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THE BUREAU OF NAVAL PERSONNEL'S MICROFICHE IMAGE TRANSMISSION S--ETC(U)

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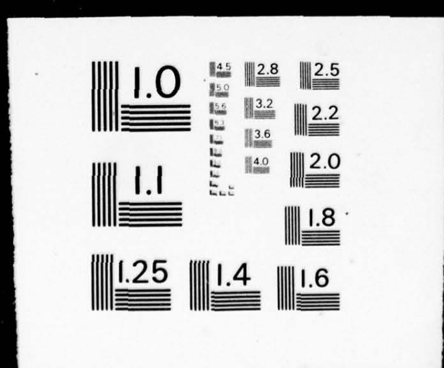

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THE BUREAU OF NAVAL PERSONNEL'S MICROFICHE IMAGE TRANSMISSION SYSTEM (MITS): A STATE-OF-THE-ART MICROFACSIMILE SYSTEM

Don Endicott

Dan Solarek

Ken Drake

OCEAN TECHNOLOGY DEPARTMENT

December 1976

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NAVAL UNDERSEA CENTER, SAN DIEGO, CA. 92132

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

R. B. GILCHRIST, CAPT, USN
Commander

HOWARD L. BLOOD, PhD
Technical Director

ADMINISTRATIVE INFORMATION

The work described in this report was conducted between 1 January and 1 December 1976 and was sponsored by the Bureau of Naval Personnel, Pers 3Db. Mr. William Hopkins was the program manager, and Mr. Robert Ambrose was the project officer. The Office of Naval Research, Code 521, funded the effort under Program Element 65862N. It is part of the ongoing effort by the Advanced Systems Division, Code 651, to develop information systems and technologies appropriate to the Navy's needs. The objective of this effort and the approaches taken to meeting them are summarized in *NUC TN 1578, Information Systems and Technologies:* What We are Doing and Why, by Dan Solarek and Ben Saltzer, September 1975.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Naval Undersea Center (NUC) has conducted a study for the Bureau of Naval Personnel (BUPERS) to analyze the options open in the design and development of a Microfiche Image Transmission System (MITS) that could distribute Navy personnel records from BUPERS' central files in Washington, D.C., to remote sites. Based upon an extensive examination of BUPERS' present Microform Personnel Records System (MPRS), the study presents a preliminary design for a prototype MITS. MITS could accommodate 300 requests per day

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with an average response time of 48 hours. Salient design features include laser-beam spinning-mirror scanners and recorders for use at the central site and remote stations; a wide-band satellite transmission link; and use of dry-processed silver-halide output film employing a newly developed fiche format. MITS offers the fastest and most reliable means of disseminating BUPERS' records. However, it is not currently competitive economically with Air Freight or the U.S. Postal Service, although technological advances will reduce its costs below those of air or postal service within 10 to 15 years. For the present, it is recommended that BUPERS rely upon certified mail for its normal transmission requirements. Additionally, it should implement an inexpensive, low-volume, low-speed microfacsimile transmission system for priority service between Washington, D.C., and major Navy centers. This approach will enable BUPERS to meet its near-future needs while monitoring technology trends for evidence that a more sophisticated system like MITS has become cost-effective.

SUMMARY

PROBLEM

Conduct an Options Analysis Study for the Bureau of Naval Personnel (BUPERS) to validate key findings of the Naval Undersea Center's (NUC) Microfiche Image Transmission System (MITS) feasibility study. Additionally, establish objective criteria to facilitate selection by BUPERS of particular cost-saving options and to recommend the most promising options in the form of a comprehensive preliminary system design. The preliminary system's design includes the selection of specific system components, system integration, human factors engineering, and cost estimating.

RESULTS

The Options Analysis Study demonstrated the following points:

1. Laser scanning of diazo microfiche is both possible and practicable.

2. The best scanning resolution for MITS is 6.3 lines per millimeter (160 lines per inch) of the full-size document or 151 lines per millimeter (3,840 lines per inch) of the actual fiche image.

3. Dry-processed silver-halide film and vesicular film will work with laser recorders. Dry silver film is the more sensitive and can thus be used for higher speed recording. Dry silver film can be exposed by a variety of lasers, but vesicular requires an argon or helium-cadmium laser.

4. Automatic stacking and handling of unitized records (in particular, diazo microfiche) is technically feasible, very reliable, and, therefore, acceptable for MITS applications.

5. An image-packed format for the MITS output fiche is not only economically practical, but is also very acceptable to MITS users (in most cases, packed fiche are easier to use than standard records).

6. A satellite transmission link is the most economical for long-distance image data transmission.

7. MITS is not now economically competitive with either Air Freight or the U. S. Postal Service. It is, however, the most reliable and most rapid transmission system which can satisfy BUPERS needs. Future cost comparisons will be more favorable as transmission costs decrease and labor costs increase.

8. MITS provides the most reliable and most rapid long-distance transmission of microfiche available. Actual transmission time averages 4 minutes per record and total turnaround time from request of record to receipt of record can be less than 1 hour. To handle the projected volume of 300 records per day in an orderly fashion, the standard turnaround will be 48 hours.

RECOMMENDATIONS

1. The recommended scanner is a laser-beam spinning-mirror scanner that scans individual microfiche images at 151 pixels per millimeter and 151 scan lines per millimeter. The recommended laser is a helium-neon laser.

2. The recommended output recorder is a laser-beam spinning-mirror recorder. The recorder and scanner should be identical devices which can either scan or record.

3. The recommended output film is dry-processed silver-halide film.

4. The recommended transmission link is a wideband satellite link with an earth station located near each remote site.

5. The image-packed format is recommended for the MITS output microfiche.

6. Normal BUPERS microfiche transmission requirements should be fulfilled by mailing the records via first class certified mail to individuals.

7. The normal mailing system should be augmented by a low-volume microfacsimile system which ties into major Navy centers for priority service.

8. A prototype low-volume, two-way transmission microfacsimile system should be implemented between Washington, D.C., and San Diego to demonstrate this priority service.

9. BUPERS should investigate the feasibility of producing small, low-volume, low-cost microfacsimile receivers for small-station and shipboard access to the microfiche records.

10. BUPERS should monitor the technology trends and postal cost trends to maintain updated awareness of the cost-effectiveness of MITS versus the alternative systems.

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1. INTRODUCTION

The purpose of this report is to present the results of the Microfiche Image Transmission System (MITS) Options Analysis Study conducted by the Naval Undersea Center (NUC) for the Bureau of Naval Personnel (BUPERS). The study had three major objectives. First, validate the key findings of NUC's MITS feasibility study, initiated during fiscal year 1975 and reported in Reference 1.1. Second, provide BUPERS with objective criteria for deciding among the potentially cost-saving options described in that study. Third, recommend the most promising options for MITS. The recommendations are presented in the form of a preliminary design as part of this report.

The MITS feasibility study examined alternative approaches to transmitting personnel records from BUPERS' central files in Washington, D. C., to major Navy centers such as San Diego, California, and Norfolk, Virginia. It showed that a microfacsimile system would be fastest but would involve the largest initial investment and recurring costs. The Option Analysis Study described in this report was an extension of the original effort. The major consideration during both efforts was to determine whether a microfacsimile system might be designed and developed that would be economically competitive with alternative transmission schemes.

MITS was made necessary by BUPERS' conversion of Navy personnel records from paper to microfiche, which began in December 1974. All officer records were converted by the first quarter of 1976. Conversion is underway on the enlisted records, and it should be completed in October 1977. The new personnel records system will consist of approximately 2,500,000 microfiche.

While the conversion of Navy personnel records progressed, Congress amended the Freedom of Information Act to allow individuals better access to records containing information about themselves and to provide them with certain control over those records. This amendment (Public Law 93-579) is commonly known as the Privacy Act of 1974, or simply the Privacy Act. It is anticipated that the Privacy Act will result in more persons wanting to review their own records.

The volume of requests is expected to increase sharply as awareness of the Privacy Act spreads. Records will eventually be sent throughout the world to satisfy this demand. As a result, a capability to transmit microfiche records from Washington, D. C., to major Navy centers such as San Diego, California, and Norfolk, Virginia, is desirable.

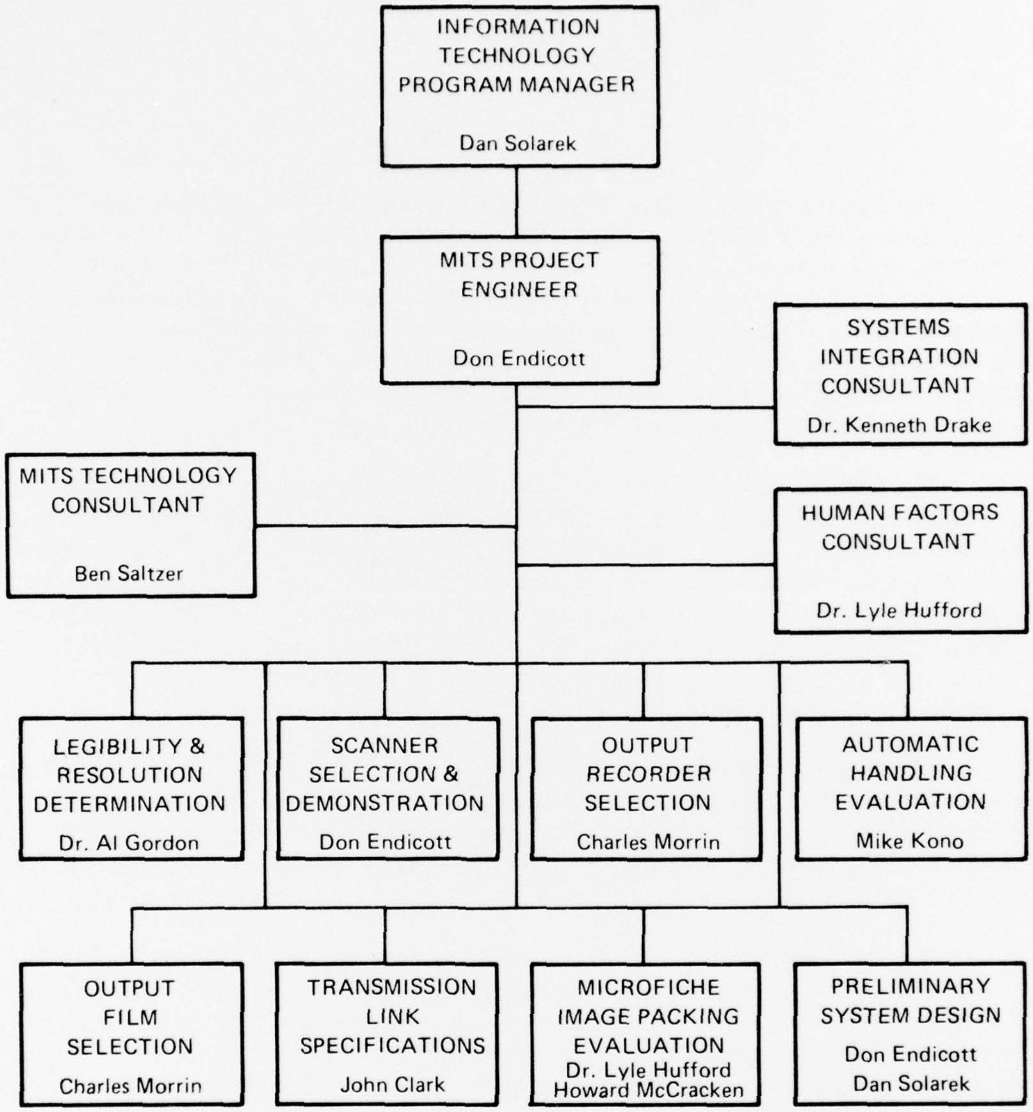


Figure 1.1. MITS options analysis phase task team organization.

The report is divided into two major parts. The first of these deals with the Options Analysis Study itself. In particular, it is a general description of MITS, its available options, exactly what options were analyzed, what was discovered about each, and the recommendations resulting from the analysis. The second part is the preliminary system design. It includes the details of putting together MITS from the components selected during the Options Analysis Study. Cost comparisons with alternative transmission systems are also included. Appendix A presents a complete system flow diagram. Appendix B presents summary position descriptions for MITS operator personnel. Appendixes C and D provide the reader with appropriate MITS definitions and an MITS subject area bibliography, respectively.

REFERENCE

1.1 Naval Undersea Center. NUC Technical Note 1562, Microfiche Image Transmission System (MITS) Feasibility Study for the Bureau of Naval Personnel, by B. Saltzer, C. Morrin, D. Griffin, D. Solarek. June 1975.

2. BACKGROUND

THE BUPERS MICROFORM PERSONNEL RECORDS SYSTEM

This section provides a brief description of the existing BUPERS Microform Personnel Records System (MPRS). It is important to be aware of the basic configuration and operation of the system to understand fully the MPRS/MITS interfaces discussed throughout this report. A more comprehensive description of the MPRS and its subsystems can be found in References 2.1 and 2.2.

The BUPERS MPRS comprises three related subsystems. The first, the File Conversion Subsystem, converts BUPERS paper personnel records to microfiche. After this conversion, the second subsystem, File Maintenance, becomes responsible for the ongoing maintenance of the fiche, updating the fiche file daily as new documents are received, creating new personnel records, and releasing records to other authorized records centers after personnel have been retired or separated from the Navy. The existence of the third subsystem, File Utilization, ensures response to the daily needs of BUPERS. Authorized users of this subsystem include satellite file users, individual users, and Selection Boards. Only the File Maintenance and File Utilization subsystems directly impact MITS.

File Conversion Overview

During the conversion process, paper personnel records are removed from BUPERS and released to the conversion contractor on a daily basis. Adequate controls are used to ensure that all records are accounted for while in the contractor's hands.

When a paper personnel record is received at the conversion line, it is checked against a listing for accountability purposes. Paper records are then input to the conversion line in batches and handled in this mode until returned to BUPERS. That is, the group of paper records making up a batch are moved from one point in the conversion line to another as a group. This practice makes it easier to keep accurate track of all records.

As part of the conversion process, the paper documents which are to be retained in individual records are grouped according to their information content. For example, all orders are put in one group, educational records in another, and fitness reports in yet another. These groupings will be maintained during filming and eventual fiche creation to facilitate location of specific documents within an individual record. Figure 2.1 shows the information categories which BUPERS has established for officers, and Figure 2.2 shows the corresponding categories for enlisted personnel.

In the conversion line, each record is purged of all extraneous and outdated material according to guidelines established by BUPERS. Deleted documents are checked by Navy personnel to ensure that no error has been made in removing the material. As mentioned above, prior to microfilming, the records being retained are formatted according to the

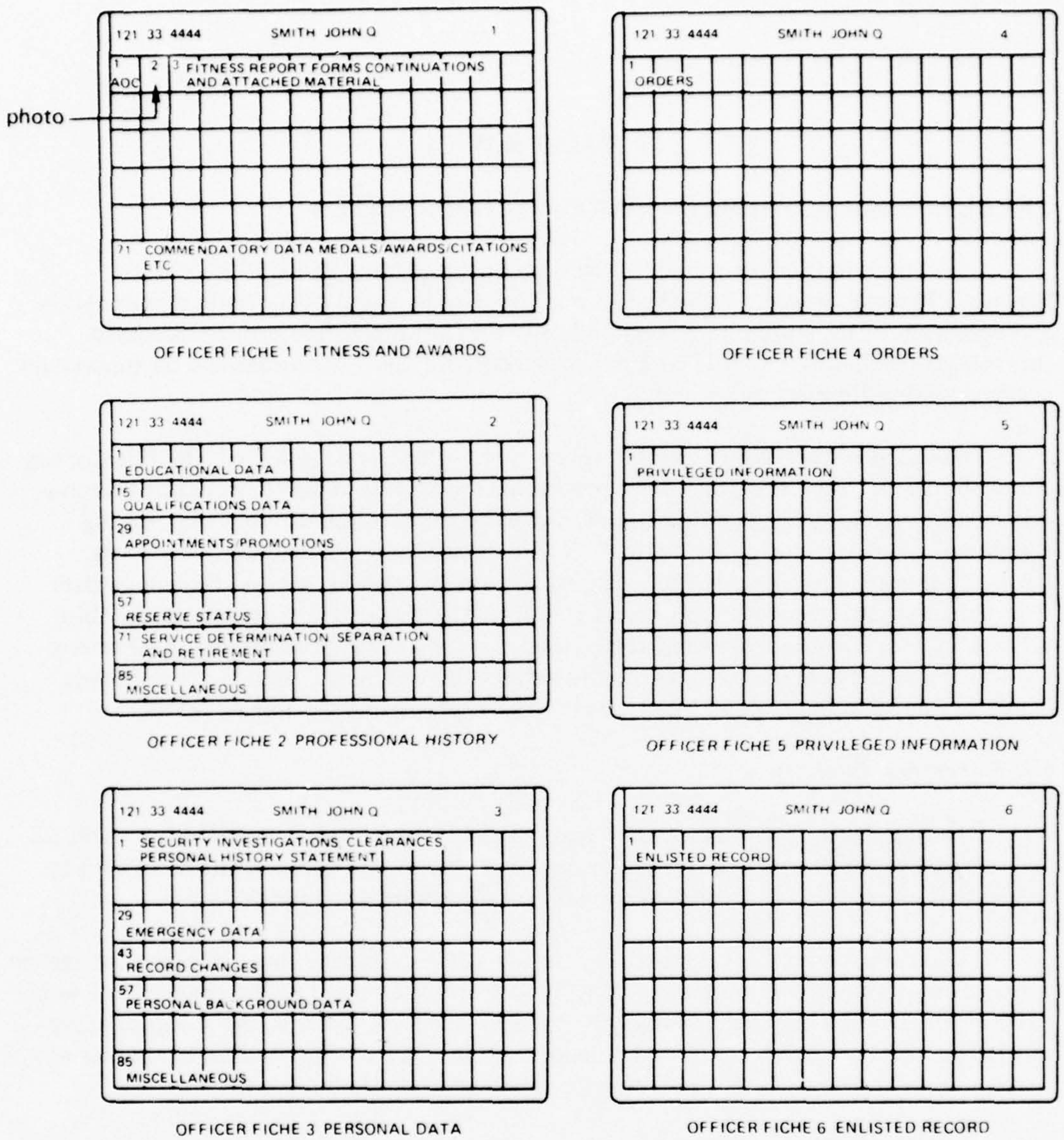
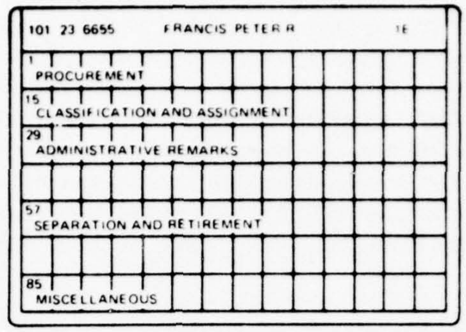
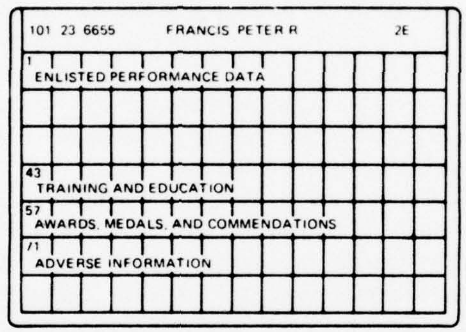


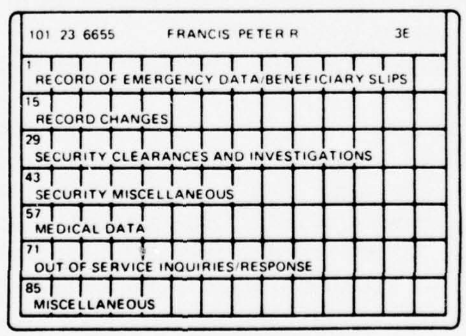
Figure 2.1. BUPERS information categories for officers.



ENLISTED FICHE 1E PROFESSIONAL SERVICE HISTORY



ENLISTED FICHE 2E
PERFORMANCE EVALUATION AND TRAINING DATA



ENLISTED FICHE 3E PERSONAL DATA

Figure 2.2. BUPERS information categories for enlisted personnel.

information categories, or fields, shown in Figures 2.1 and 2.2. The formatted record is then photographed by means of cameras modified to provide the highest quality photographic image. The resultant imagery is mounted in the appropriate fields on prelabeled fiche carriers by a semiautomated mounting device. The mounting device is controlled by a computerized system which relates the image locations on the microfilm roll to the fields on the microfiche. This technique of mounting microimages in a grid pattern on a substrate is commonly known as the strip-up method of creating microfiche. After mounting, the completed fiche is inspected, and errors or deficiencies are corrected. The records, now in fiche format, are returned to BUPERS where they are filed, maintained, and made available for authorized use.

File Maintenance Overview

Several primary activities are conducted in the file maintenance line, i.e., updating microfiche records, creating new fiche records for officer and enlisted personnel, and retiring records as appropriate. The largest effort is expended in updating the microfiche records. This is accomplished by a series of work stations, each performing a unique task. Paper documents to be added to an individual's record are received, sorted, sequenced by Social Security Number (SSN), and collected into batches. Inputs are made to the computerized process control system by means of a cathode ray tube (CRT) terminal to update the data base with the additional images and to create and store the mounter drive commands. The inputting of this information is necessary because the computer automatically calculates the image assignments for the imagery on the microfilm roll and simultaneously updates its assignment data base. This data base contains information about the last used image location in each field of all records in the MPRS. The batched personnel documents are photographed using a modified planetary camera, and the resultant roll of microfilm is processed and prepared for image inspection and assignment. Rolls are viewed on a roll film reader and made ready for mounting by attaching an adhesive strip along each edge.

When the image location assignment is made, a paper pull list of the records to be updated is generated by the computer controller and is used by file storage personnel to retrieve the master fiche. The master fiche are located in large semiautomatic storage and retrieval devices. Once retrieved, the master fiche are sent to the mounting station, where the roll and batch of fiche carriers are assigned to a semiautomated mounter. Each mounter is computer-driven, and, when loaded with the film roll and activated, the images are attached to each fiche carrier under the direction of the computer drive commands mentioned earlier. Operator involvement is limited to placing the master fiche carriers on the mounter, verifying the transaction, and removing the completed fiche.

Fiche to be retired to the Federal Records Center (FRC) are processed in a separate manner. Inputs are fed into the computer regarding individuals retired, and related data base information is erased. Each fiche to be retired is permanently removed from the master file. Individual fiche are duplicated on a film-duplicating device that produces a set of copies meeting all archival standards. After all special film processing is completed, the copies are shipped to the FRC for permanent storage.

Maintenance activities are performed daily over a two-shift period. The system is designed to handle normal updates within a 3-day period. It also provides an activity

designated "Blue Streak," wherein Officers Fitness Reports are given priority processing, allowing updating to be completed within one day after a fitness report is received.

Figure 2.3 presents the workflow of the BUPERS File Maintenance Subsystem.

File Utilization Overview

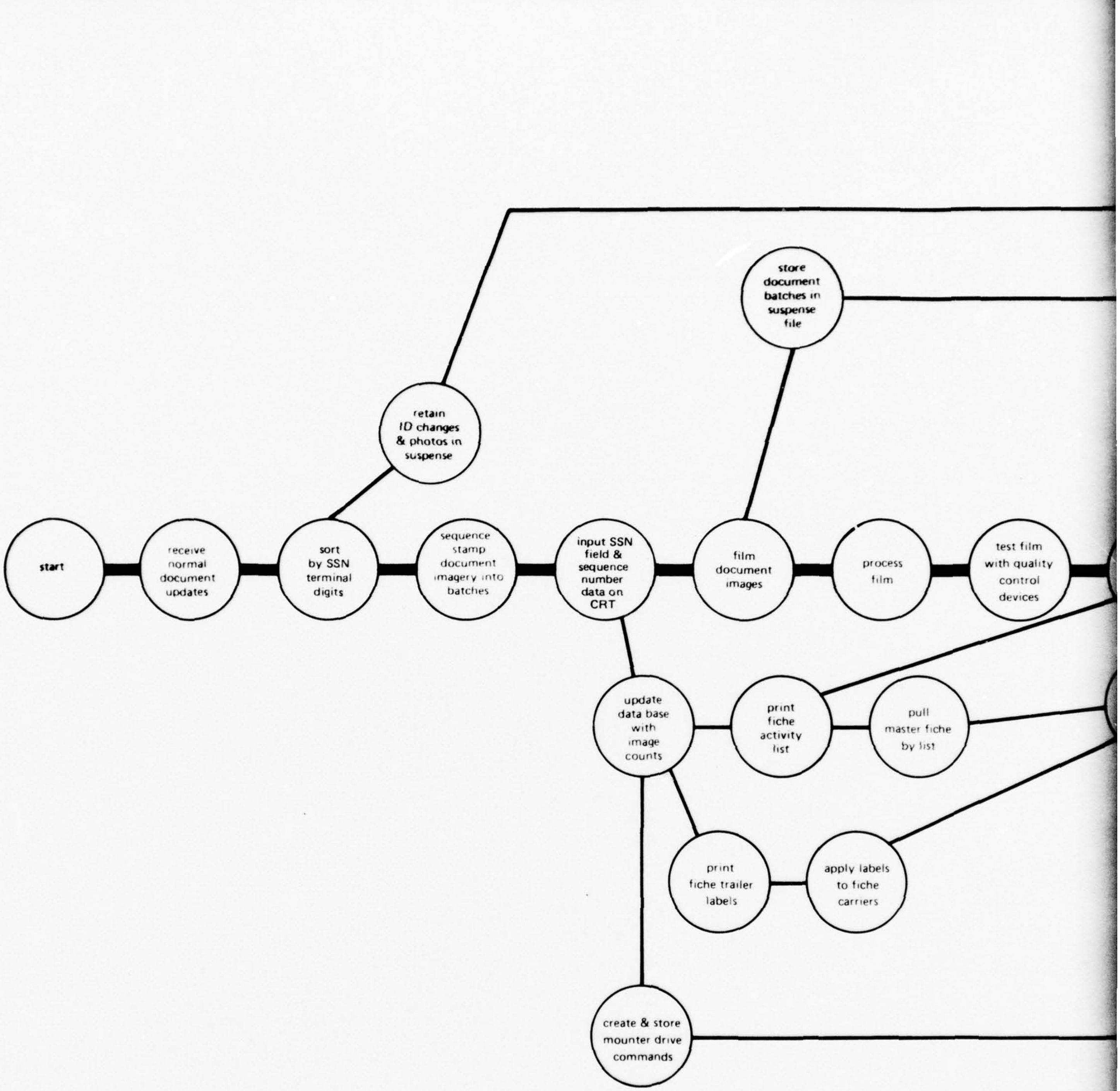
The two principal categories of record users at BUPERS are BUPERS personnel and Selection Board members. The File Utilization Subsystem is designed to satisfy the requirements of both categories. Record requests are made via "Request Chits" prepared by authorized BUPERS personnel. The request is filled by retrieving the master fiche, duplicating it on a diazo duplicating device, and sending the duplicate to the requester. Master fiche are then refiled to permit immediate response to the next user. Selection Board requests are handled in a similar manner; however, the pulling, duplicating, and refiling operations to fill these requests are on a much larger scale and are batched for processing.

The capacity exists to convert film imagery to paper copy when necessary. This is a relatively minor activity, since file users are ordinarily provided viewers for reading fiche.

To enhance file utilization, 35 satellite files have been established to service high-volume users. Each satellite file containing copies of Officer Fitness Report fiche is designated according to areas of user responsibility. The satellite files are updated by the File Maintenance Subsystem.

Accountability for fiche copies is maintained at the document custodian station. Copies of request chits are held in a suspense file until the diazo copy is returned. To ensure confidentiality of fiche data, all returned diazo copies are destroyed by disintegrator equipment.

Figure 2.4 presents the workflow of the BUPERS File Utilization Subsystem.



retain ID changes & photos in suspense
store document batches in suspense file
start
receive normal document updates
sort by SSN terminal digits
sequence stamp document imagery into batches
input SSN field & sequence number data on CRT
film document images
process film
test film with quality control devices
update data base with image counts
print fiche activity list
pull master fiche by list
print fiche trailer labels
apply labels to fiche carriers
create & store mounter drive commands

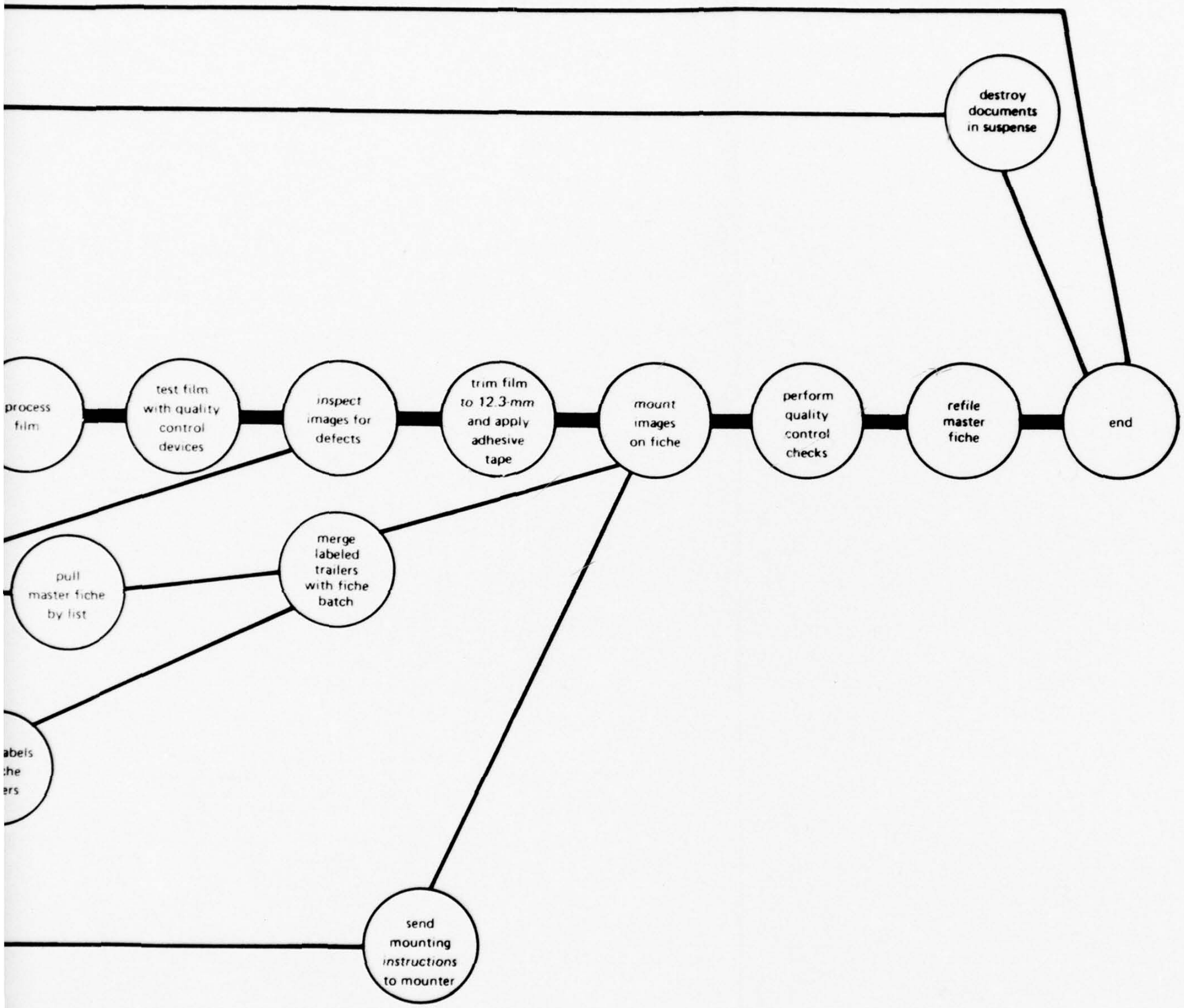
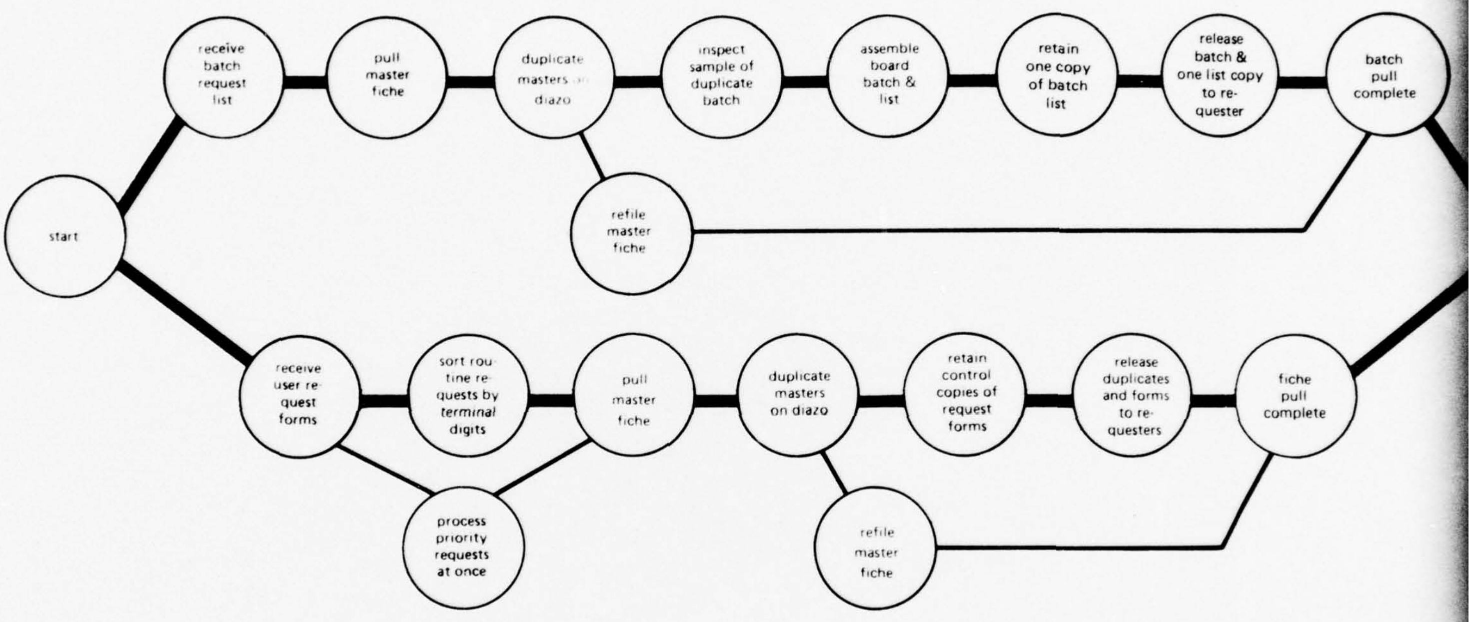


Figure 2.3. BUPERS file maintenance subsystem workflow.


start
receive batch request list
pull master fiche
duplicate masters on diazo
inspect sample of duplicate batch
assemble board batch & list
retain one copy of batch list
release batch & one list copy to re-quester
batch pull complete
refile master fiche
receive user re-quest forms
sort rou-tine re-quests by *terminal* digits
pull master fiche
process priority requests at once
duplicate masters on diazo
retain control copies of request forms
release duplicates and forms to re-questers
fiche pull complete
refile master fiche

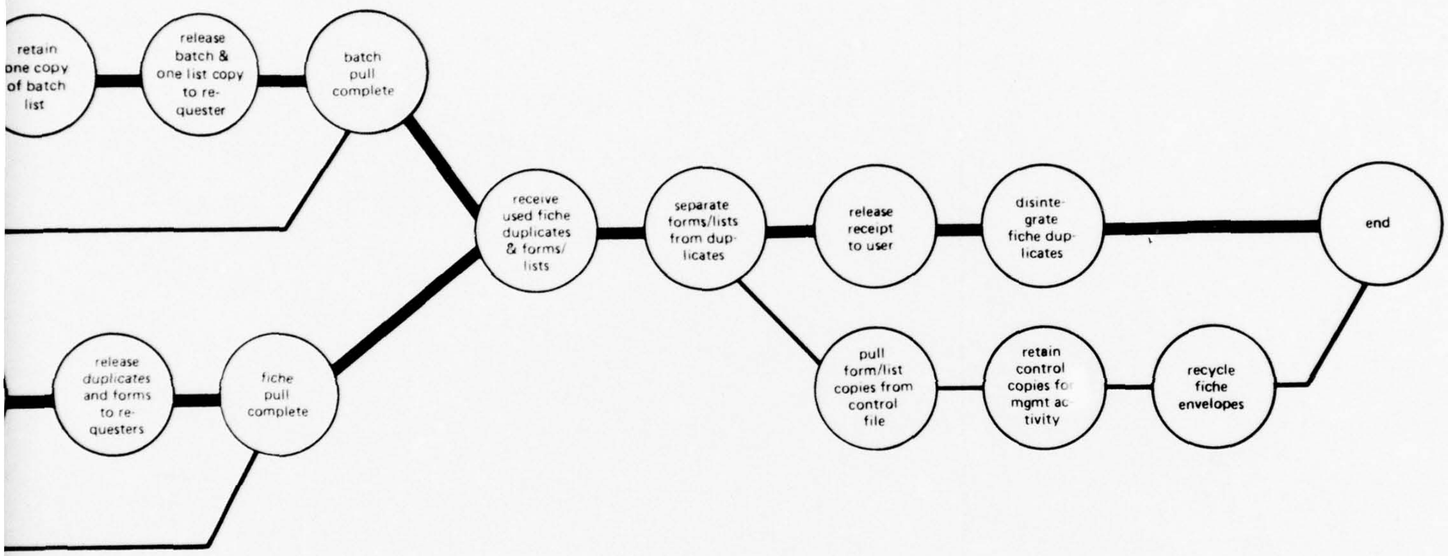


Figure 2.4. BUPERS file utilization subsystem workflow.

OVERVIEW OF MITS

This section presents an overview of MITS, the electronic transmission system concept first discussed in Reference 2.3. It is intended as an introduction to the hardware and procedural (human) functions necessary to accomplish microfacsimile transmission. A detailed description of the system components and personnel requirements and how they fit into an operational MITS can be found in the Options Analysis Phase and System Design sections of this report.

Relationship to Existing MPRS/BUPERS Functions

Even before passage of the Privacy Act, BUPERS was required to make records available to individuals for review. Figure 2.5 shows the current system used for delivering copies of personnel records to the individuals. As the figure shows, while paper records are being converted to microfiche, two record systems are being maintained. An individual's record exists in one system or the other but not both. Now, as in the past, these records are made available to individuals who visit the Bureau or to individuals who write to

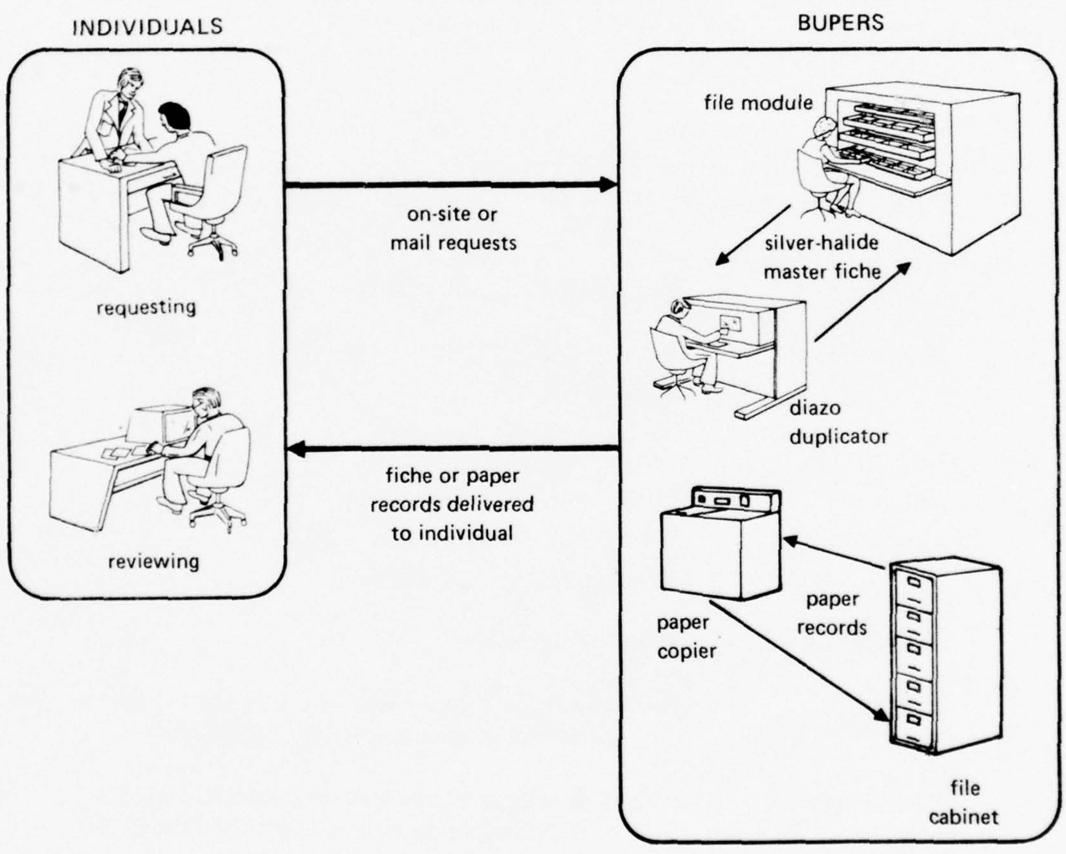


Figure 2.5. Current system for delivering copies of personnel records to individuals. Requesting and reviewing of records are done on-site at BUPERS or remotely by the U.S. Mail. Records are either in the microform system or the paper system, not both.

BUPERS and are then mailed a paper or microfiche copy of the record directly. Both of these methods are very expensive because of copying and mailing costs. As Figure 2.6 shows, MITS is intended as a system for improving access to microfiche personnel records by individuals. MITS itself will be transparent to the requesters. It will simply provide faster and more reliable access to records. Figure 2.6 also shows that the paper records system at BUPERS will be phased out as the MPRS is completed. As a result, paper copies of records will become even more expensive to produce.

Design Goals

Table 2.1 lists the original design goals for MITS. These goals force certain technical constraints on the hardware chosen for system implementation. However, these can be translated into a simple problem statement. In functional terms, the basic problem is to transmit requested microfiche images from the central site in Washington, D.C., to remote sites both quickly and economically. Implied in this statement are the functions of request for records at a remote site, storage and retrieval of the microfiche from files at the central site, image scanning, data transmission, reception of the image data at the remote site, and output copy production. Not implied but equally important are the functions of copy distribution and the necessary system control functions.

Table 2.1. MITS design goals.

Input	Standard National Micrographics Association (NMA) 24X, 98-image microfiche (Navy Personnel Records)
Central Site	Washington, D.C. (BUPERS)
Remote Site(s)	San Diego, CA Norfolk, VA Honolulu, HI
Volume(s)	300 records/day to San Diego 300 records/day to Norfolk 100 records/day to Honolulu
Turnaround	48 hours maximum
Output	Facsimile 24X, 98-image microfiche (no less than one resolution chart loss from the input fiche)
Confidentiality	Personnel records will be treated as administratively confidential, in accordance with the Privacy Act of 1974
Cost	Competitive with alternative approaches, U.S. Mail, in particular

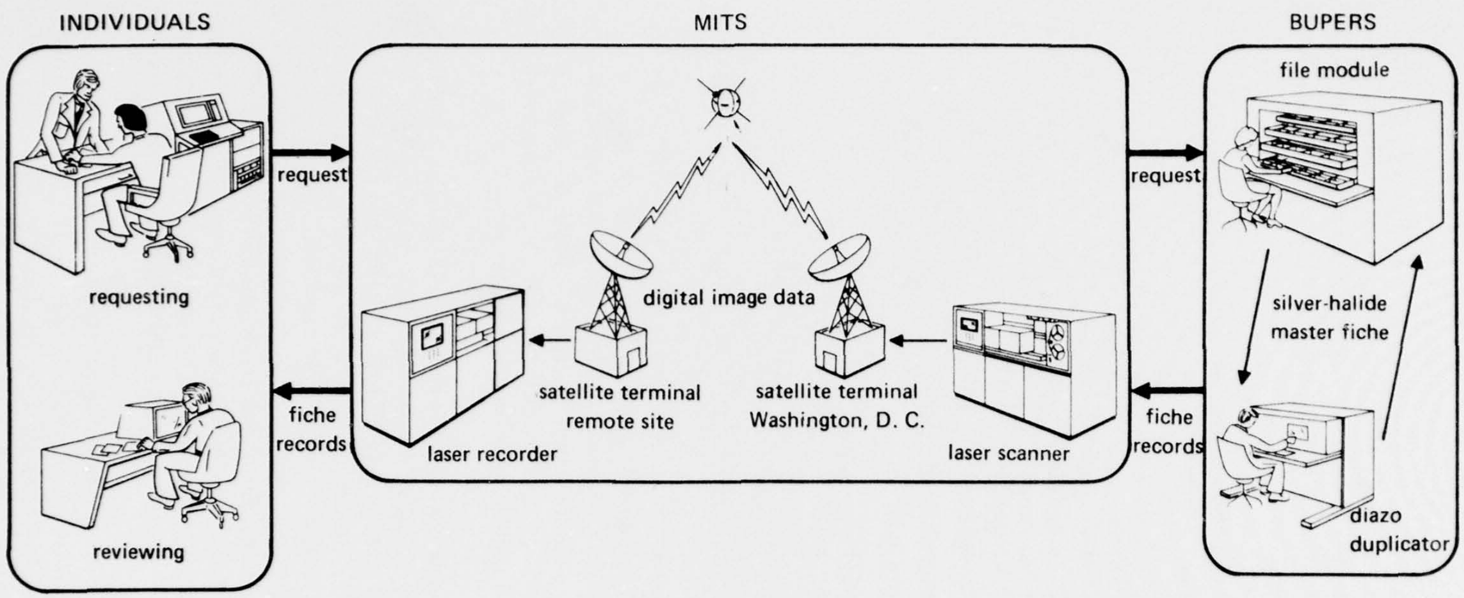


Figure 2.6. Function of MITS for improving the delivery of copies of personnel records to individuals. Requesting and reviewing of records are done at the remote site. MITS is transparent to the users, providing only faster and more reliable delivery of the copy records.

Functional Description

The purpose of this section is to provide a general understanding of MITS without providing too many details of component operation. To this end, the major functions (both human and machine) necessary to deliver a requested record to an individual are discussed. They are presented in the order of their occurrence, beginning with the individual asking to see his record at a remote site and ending with the viewing of the appropriate facsimile record at the same location.

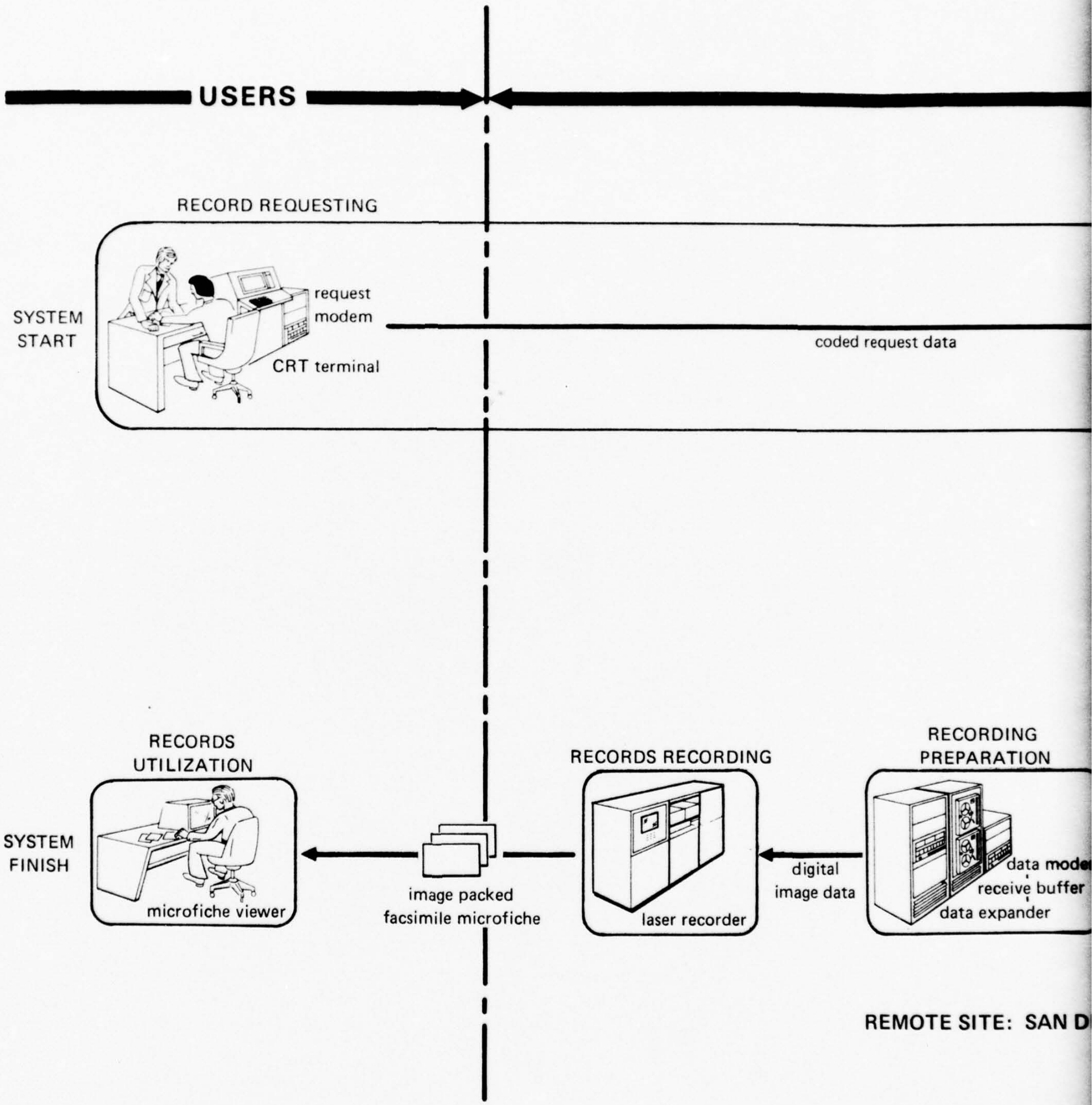
MITS can be conveniently discussed by dividing the system into the eleven major functional areas listed below:

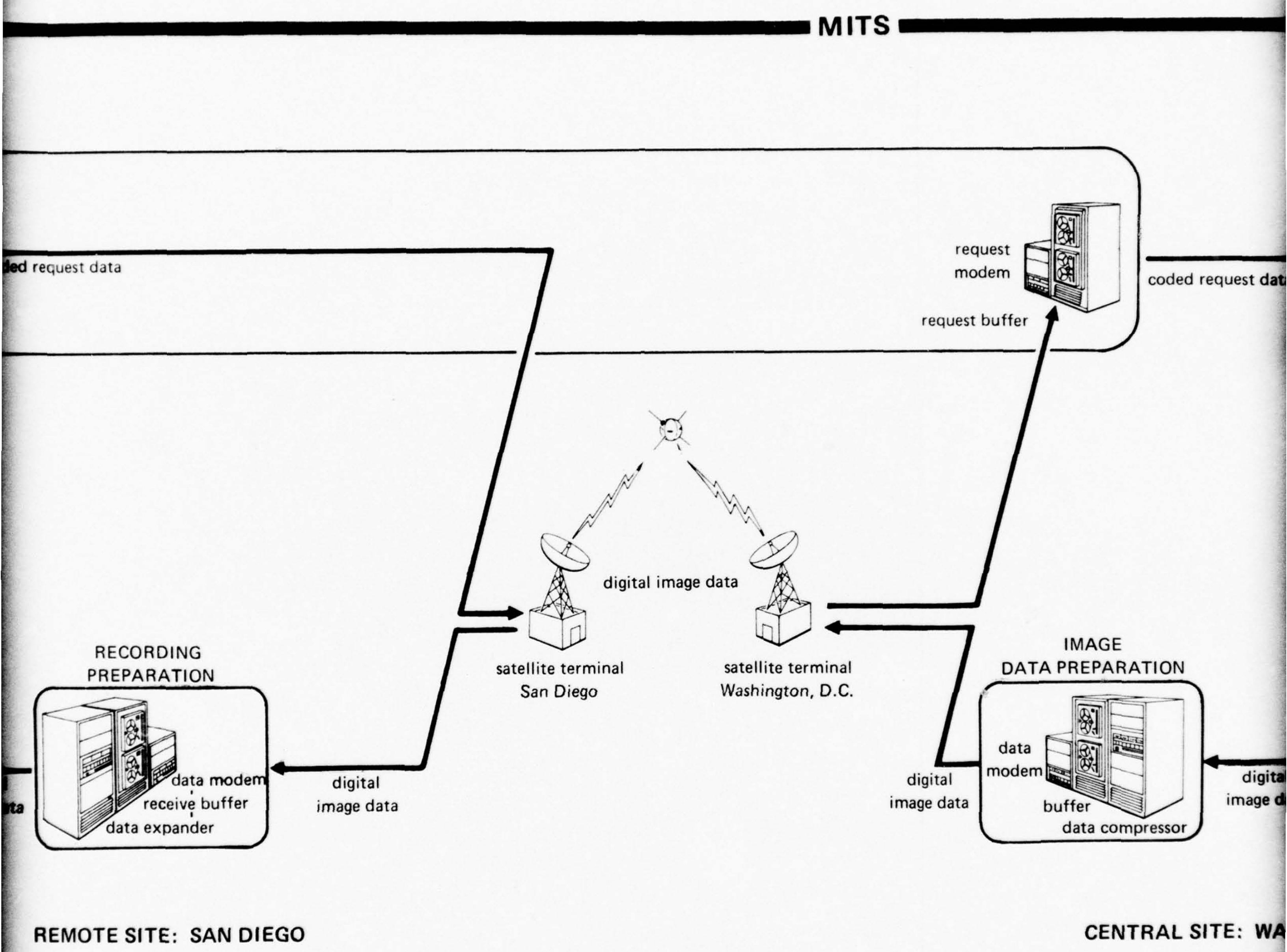
1. Records Requesting
2. Central Site Control
3. Records Preparation
4. Records Scanning
5. Image Data Preparation
6. Data Transmission and Reception
7. Remote Site Control
8. Data Recording Preparation
9. Records Recording
10. Service Control
11. Records Utilization.

Figure 2.7 is a graphic block diagram of MITS. At the left of the figure is the interface with the individuals who request copies of their records via the system. For this discussion, these individuals are called users. At the right of the figure the interface with the BUPERS MPRS is shown. A comparison of Figures 2.6 and 2.7 shows that Figure 2.7 is simply an expansion of the center block of Figure 2.6. In this expanded version the major functional areas and the details of each are shown.

Beginning in the upper left-hand corner, an individual at a remote location, e.g., San Diego, California, requests a copy of his record. The request is placed in person at the remote site office. This allows remote site operators to identify the requester and ensure that a proper request is transmitted to the central site, Washington, D.C. The request information is transmitted via satellite to the central site for validation and temporary storage. The collected requests are periodically processed to generate a list of records which are to be retrieved from the MPRS master file and entered into MITS. A printed list of Social Security numbers is delivered to the MPRS and the corresponding diazo duplicate records are returned to MITS. The duplicate records are scanned with a laser to produce an electronic representation of the imagery in preparation for transmission back to the remote site.

At the remote site, the electronic signal representing the microfiche record is used to drive a laser recording device which recreates the record imagery on silver-halide film at its original magnification. This facsimile record is then delivered to the requester for review. The whole process will take no more than the 48 hours specified in Table 2.1. However, depending upon the system workload, it could take less than a single 8-hour work day.


USERS
RECORD REQUESTING
SYSTEM START
request modem
CRT terminal
coded request data
RECORDS UTILIZATION
SYSTEM FINISH
microfiche viewer
image packed facsimile microfiche
RECORDS RECORDING
laser recorder
digital image data
RECORDING PREPARATION
receive buffer
data expander
REMOTE SITE:



MITS
request data
request modem
request buffer
coded request
digital image data
satellite terminal San Diego
satellite terminal Washington, D.C.
RECORDING PREPARATION
data modem
receive buffer
data expander
digital image data
IMAGE DATA PREPARATION
data modem
buffer
data compressor
digital image data
digital image
REMOTE SITE: SAN DIEGO
CENTRAL SITE: WA

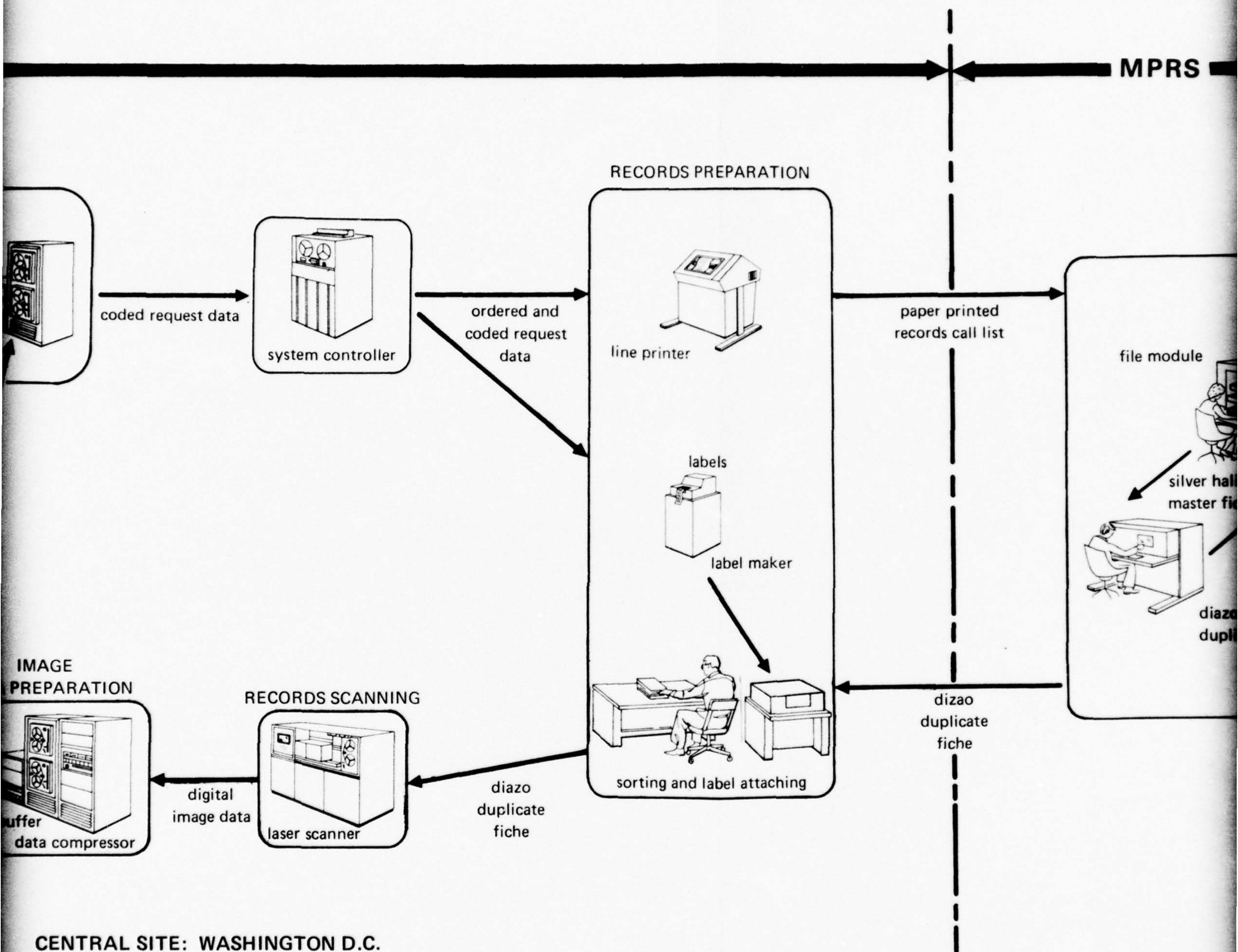


Figure 2.7. Graphic block diagram of MITS.

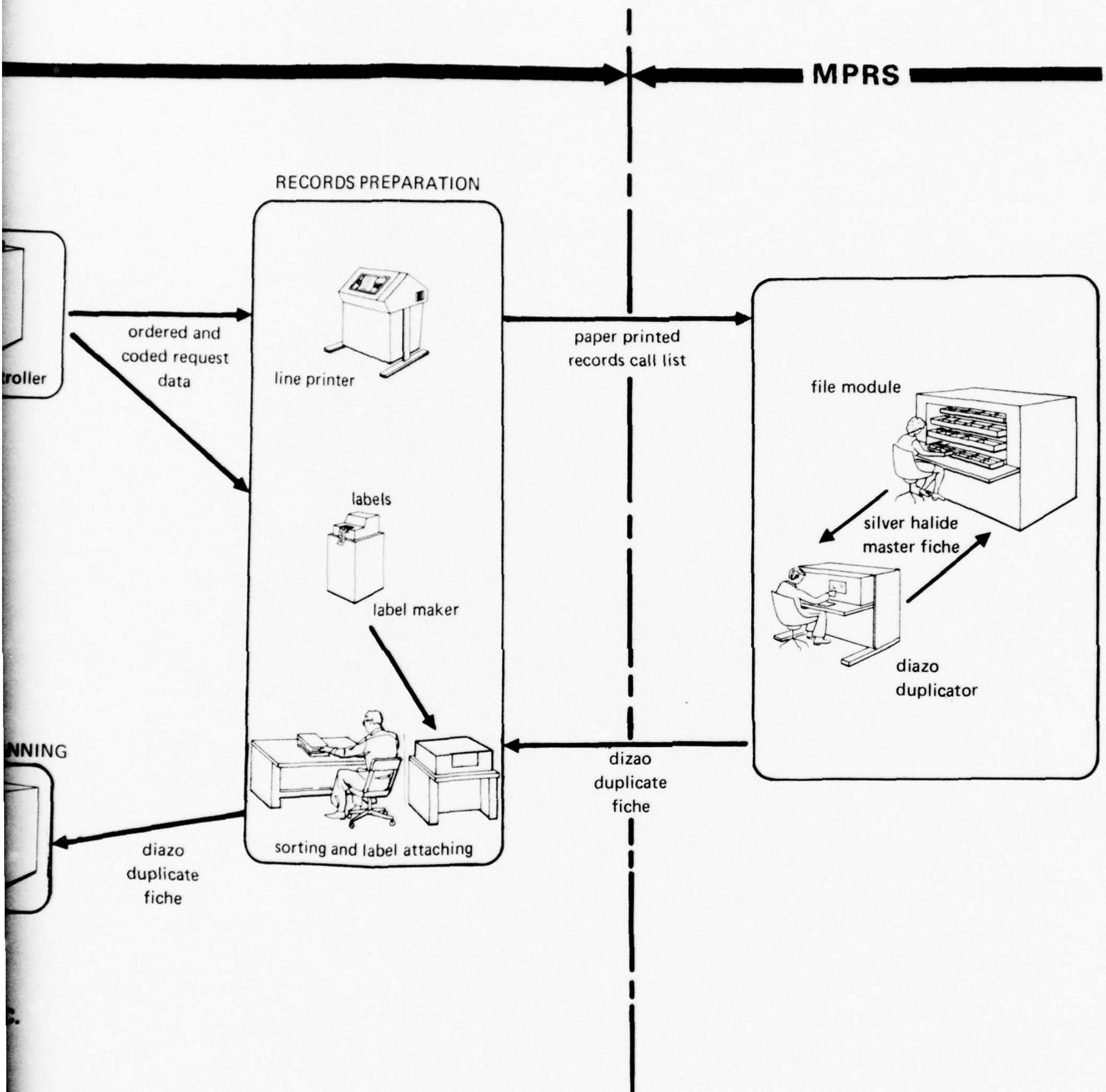


Figure 2.7. Graphic block diagram of MITS.

OVERVIEW OF THE MITS IMPLEMENTATION PLAN

This section briefly discusses the logical progression of steps necessary to design, develop, and implement a fully operational MITS. As is appropriate for a document of this type, only the major steps are shown. Time relationships are indicated but they are by no means absolute. The phases provide logical breaks for such activities as review and acquisition of funding.

Figure 2.8 is a simplified schedule of the steps necessarv to implement MITS. As shown in this figure, there are four major phases of implementation. The first of these, already complete, was a feasibility study which determined that MITS was technologically feasible. This phase was completed in May 1975. The second phase is an options analysis, which is basically an extension of the feasibility effort. Emphasis during this phase has been on studying the potential cost-saving options suggested during the feasibility stage, refining the cost estimates, and producing a preliminary system design. The third and longest phase is prototype development. During this period, the preliminary design will be completed and the system will be constructed. It is anticipated that a prime contractor will work very closely with NUC project personnel to accomplish this phase of the project. Implied in the prototype phase is an evaluation of the procedures and components required for a workable system. The fourth and final phase is the operational phase. It is during this phase that additional remote sites will be added and all sites will be made to operate at full volume on a daily basis.

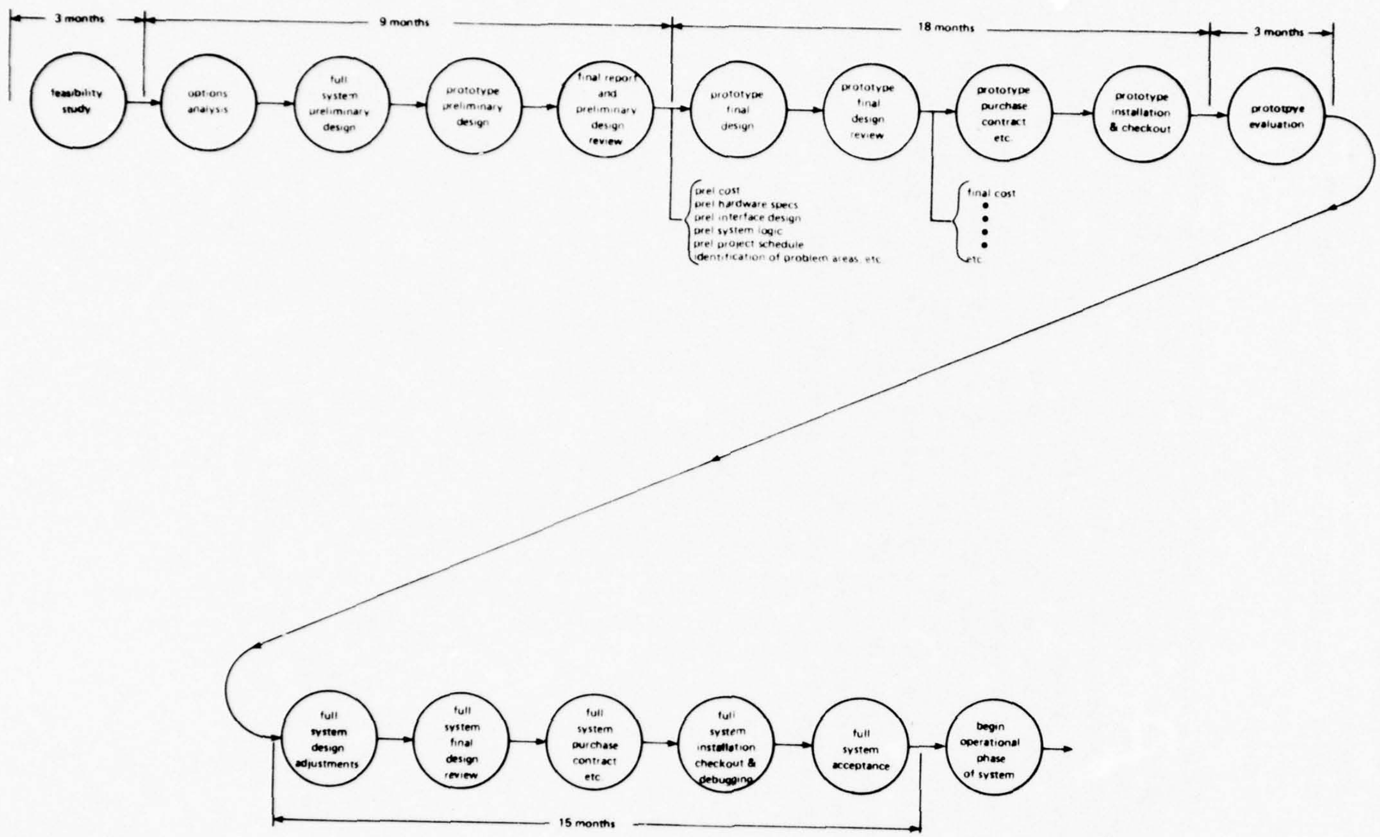


Figure 2.8. Schedule for development of MITS prototype and full system. The full system includes all major remote sites.

OTHER APPLICATIONS FOR MITS

Although the MITS project has been aimed at satisfying immediate Navy needs, there are several other potentially important applications for the system. With very little modification MITS could directly satisfy Fleet needs for other microform information. For example, small, low-volume output recorders could be located aboard ships or at small field stations. These would allow for transmission of directives, technical manuals, training materials, personnel records, and even tactical information via a satellite link.

Perhaps the most obvious alternative application of MITS lies with other military personnel centers. Both the Army and Air Force personnel centers are converting their records to microfiche. Both are aware of the MITS project and have expressed a keen interest in its outcome. Their potential applications for MITS are similar to that of BUPERS. Since the Army's system is also located in the Washington, D.C., area, it is possible that a shared MITS will be practical.

Another potential application for MITS is related to the U.S. Postal Service's electronic message service system (EMSS). EMSS involves many existing and near-future technological concepts, including the use of facsimile as an alternative to transporting paper over long distances. This effort by the Postal Service and its prime contractor, RCA, coupled with the increased use of micropublishing and microfiche in general, points to a very promising application for MITS.

A more immediate application of the MITS capabilities is found at the Defense Documentation Center (DDC). DDC maintains thousands of technical reports in a well-organized and computerized storage and retrieval system. In conjunction with the National Technical Information Service (NTIS), they also make microfiche copies of these documents available to all of the DoD. Delivery of the microfiche copies is currently accomplished by mail, taking as long as two or three weeks. MITS could greatly enhance the distribution process, and, in turn, the usefulness of the technical report to DoD projects.

Yet another application for MITS can be found as part of the Navy Technical Information Presentation Program (NTIPP), formerly the Navy Technical Manual System (NTMS). This program is underway at the David Taylor Naval Ship Research and Development Center (DTNSRDC). Its primary objective is to investigate ways for producing, updating, and distributing technical manuals (as well as other information) for Fleet use. With the trend for these manuals to be available in microfiche form, MITS has an obvious application.

It is with this wide range of potential applications in mind, as well as the immediate BUPERS needs, that BUPERS has pursued the feasibility study and options analysis phase of MITS.

REFERENCES

2.1. PRC Information Sciences Company. Bureau of Naval Personnel (BUPERS) Microform Personnel Records System, Implementation Plan. PRC, McLean, VA: Volume I: Technical Summary, Revised November 1975.

2.2. ______. Bureau of Naval Personnel (BUPERS) Microform Personnel Records System, Implementation Plan, Volume III. System Maintenance and Utilization, Revised November 1974.

2.3. Naval Undersea Center. NUC Technical Note 1562, Microfiche Image Transmission System (MITS) Feasibility Study for the Bureau of Naval Personnel, by B. Saltzer, C. Morrin, D. Griffin, and D. Solarek. June 1975.

3. OPTIONS ANALYSIS TASK DESCRIPTION AND RESULTS

The options analysis was performed to accomplish three major objectives. The first was to validate the key findings of the MITS feasibility study. The second was to provide BUPERS with objective criteria for deciding among potentially cost-saving options described in that study. The third objective was to recommend the most promising options for MITS by way of a preliminary system design with specific component recommendations.

The particular options investigated required the following tasks:

1. Determine the required resolution for scanning the microfiche.
2. Verify the practicability of laser scanning diazo copies of the master fiche.
3. Explore the practicability of writing with an off-the-shelf computer output microfiche (COM) recorder onto dry silver and/or vesicular film.
4. Investigate the practicability and reliability of stacking and automatically feeding diazo copies into a scanner.
5. Evaluate the NUC image-packing concept for combining output images onto a minimum number of output microfiche.
6. Prepare a preliminary system design and cost analysis.

INPUT CONSIDERATIONS

Resolution Determination

The first input consideration with significant impact on the entire MITS design is the determination of the scanning resolution required to enable a human to read the output microfiche. The need for this subtask arises from the mechanics of the scanning process. A scanning device must input the fiche, scan the microimages to detect the relative image densities, and produce a representative digital output. The number of data in this digital output stream increases as the resolution (i.e., number of scan lines) increases. It is desirable to scan at the lowest resolution which will produce legible output copy, since the amount of bandwidth (and hence, cost) required for the transmission link is a function of the square of the resolution. By halving the resolution, the bandwidth and recurring link cost are divided by four.

In line with the considerations described above, the purpose of this subtask was to investigate the factors affecting resolution of scanned imagery and to recommend a range of scanning densities (measured in scan lines per unit distance) which will give adequately legible microfiche at the MITS remote sites. Toward this end, the concepts of resolution, modulation transfer function, and legibility were reviewed in order to specify a quantitative measure of the quality of the scanner's output. Past studies on legibility were used to relate the scanning system's measures of quality to the resulting legibility.

The resolution specified by BUPERS for the MITS output copies was 120 line pairs per millimeter (6096 lines per inch). However, legibility researchers have found that it is possible to scan at lower resolution and still produce highly legible facsimile output. The effect of reducing the scanning resolution is to reduce the number of data bits to be transmitted, and hence, reduce the transmission costs. Therefore, the MITS task team set out to determine the minimum resolution required for MITS.

The word resolution, even when used in the technical literature, does not refer to a single concept. All too often, the particular measure of resolution being considered is left vague and undefined, leading to much confusion. Even if the type of resolution is identified, the units of measure are not. This leads to further ambiguities. The review of scanning resolution literature resulted in the selection of resolving power as the appropriate measure of resolution for MITS. A discussion of the alternative theories is found in Reference 3.1.

The advantages of using resolving power as a measure of resolution include the following:

1. It is a measure of total system performance, including human observer.
2. It is easy to determine experimentally.
3. Previous studies have correlated this type of resolution with recognition and legibility of various types of symbols.

The main disadvantage of this measure is that it is somewhat subjective (but then, so is legibility), and one can expect some variance between observers. This can be minimized by using carefully controlled experimental conditions. The study in Reference 3.1, using resolving power to predict performance of MITS-produced output microfiche, concluded that the MITS resolution should be 6.3 lines per millimeter (160 lines per inch) for legible reproduction of

lower case, 6-point typewritten characters. (A point of type is 1/72 of an inch. Upper case 6-point is 6/72 of an inch high, whereas lower case 6-point type is 3/72 of an inch high.) The study conclusions are summarized in Table 3.1. The 6.3-line-per-millimeter determination was based on an averaging of the in-context and out-of-context legibility requirements.

Table 3.1. MITS scanning requirements for various type sizes.

Type Size (points)	Required Number of Scan Lines/Millimeter (lines/inch)	
	Material in Context	Material Out of Context
11	3.11 (79)	3.86 (98)
10	3.39 (86)	4.25 (108)
8	4.25 (108)	5.31 (135)
6	5.67 (144)	7.09 (180)

A series of resolution tests was performed to evaluate the potential scanning resolution for MITS facsimile transmission. As a result of these tests, output reproductions of microfiche were obtained at four resolutions as shown in Table 3.2. Reference 3.2 provides a complete description of the equipment, materials, and procedures for the resolution tests.

Table 3.2. Resolution test summary.

Test Number	Spot Size (micrometers)	Facsimile Resolution (pixels per millimeter : pixels per inch)
1	2.5	16.7 : 423
2	5.0	8.3 : 212
3	10.0	4.2 : 106
4	20.0	2.1 : 53

Sample blowbacks of scanner-reproduced microimages are shown in Figures 3.1 through 3.3. These are shown reduced approximately 50 percent from the full-size original document. They correspond to a particular image from the original diazo duplicate and the scanner outputs of tests 2 and 3. Figure 3.1, the diazo duplicate blowback, illustrates the original input copy quality. Figure 3.2 represents an output of test 2, performed at 8.3 facsimile lines per millimeter (212 lines per inch), and Figure 3.3 represents an output of test 3, performed at 4.2 facsimile lines per millimeter (106 lines per inch). In Figure 3.3, the smallest type present, lower case 8-point, is legible. This confirms the prediction of Table 3.1 that 8-point type will be legible in context when the image is scanned at 4.2 lines per millimeter.

A comparison of Figures 3.2 and 3.3, shows the improvement in image quality at a resolution of 8.3 lines per millimeter. These two samples bracket the recommended MITS resolution of 6.3 lines per millimeter. The predictions of legibility of particular type sizes as a function of scanning resolution were confirmed by having a group of NUC personnel read

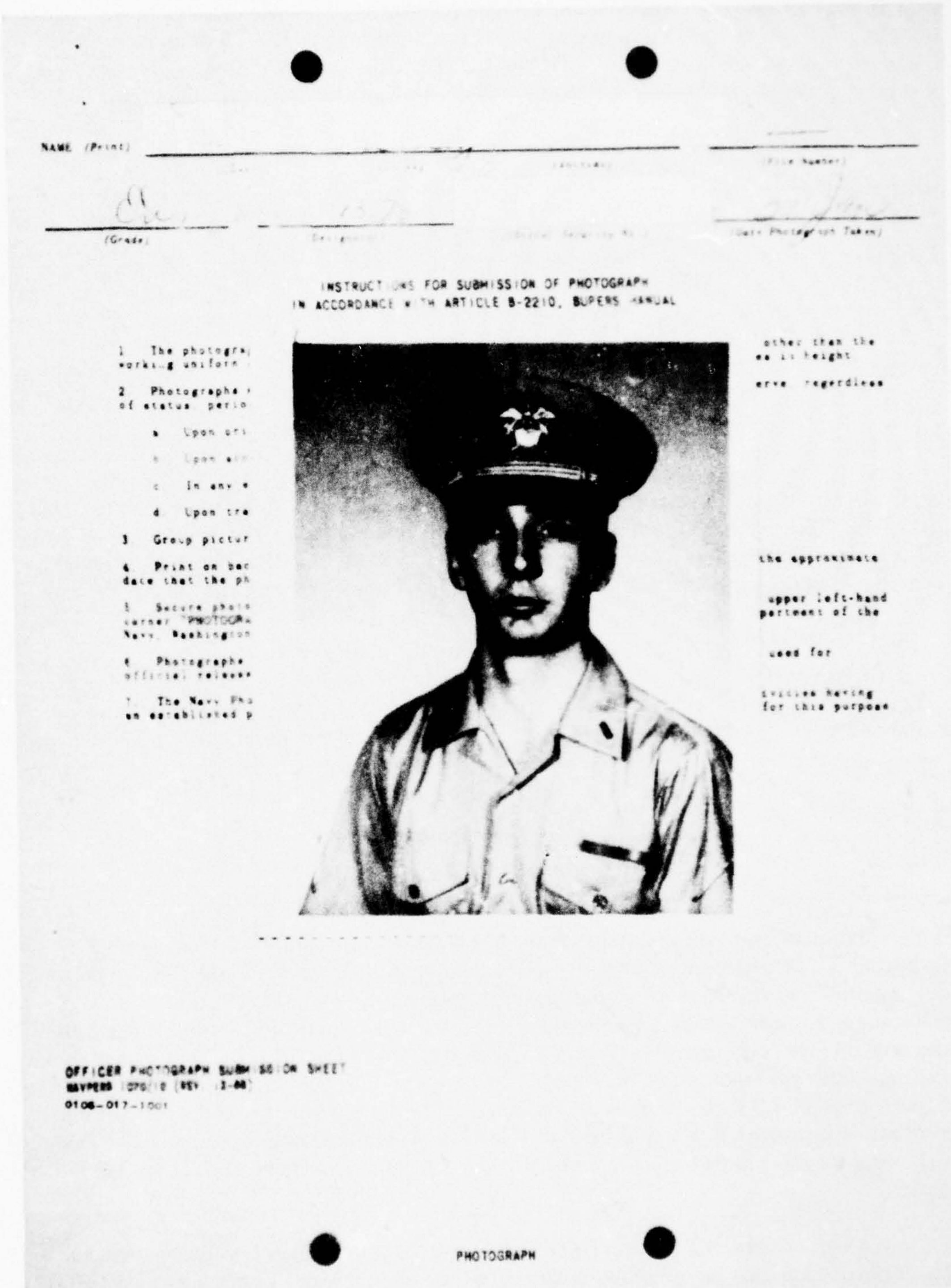


Figure 3.1. Original officer photograph from fiche 1.
(Shown photo reduced)

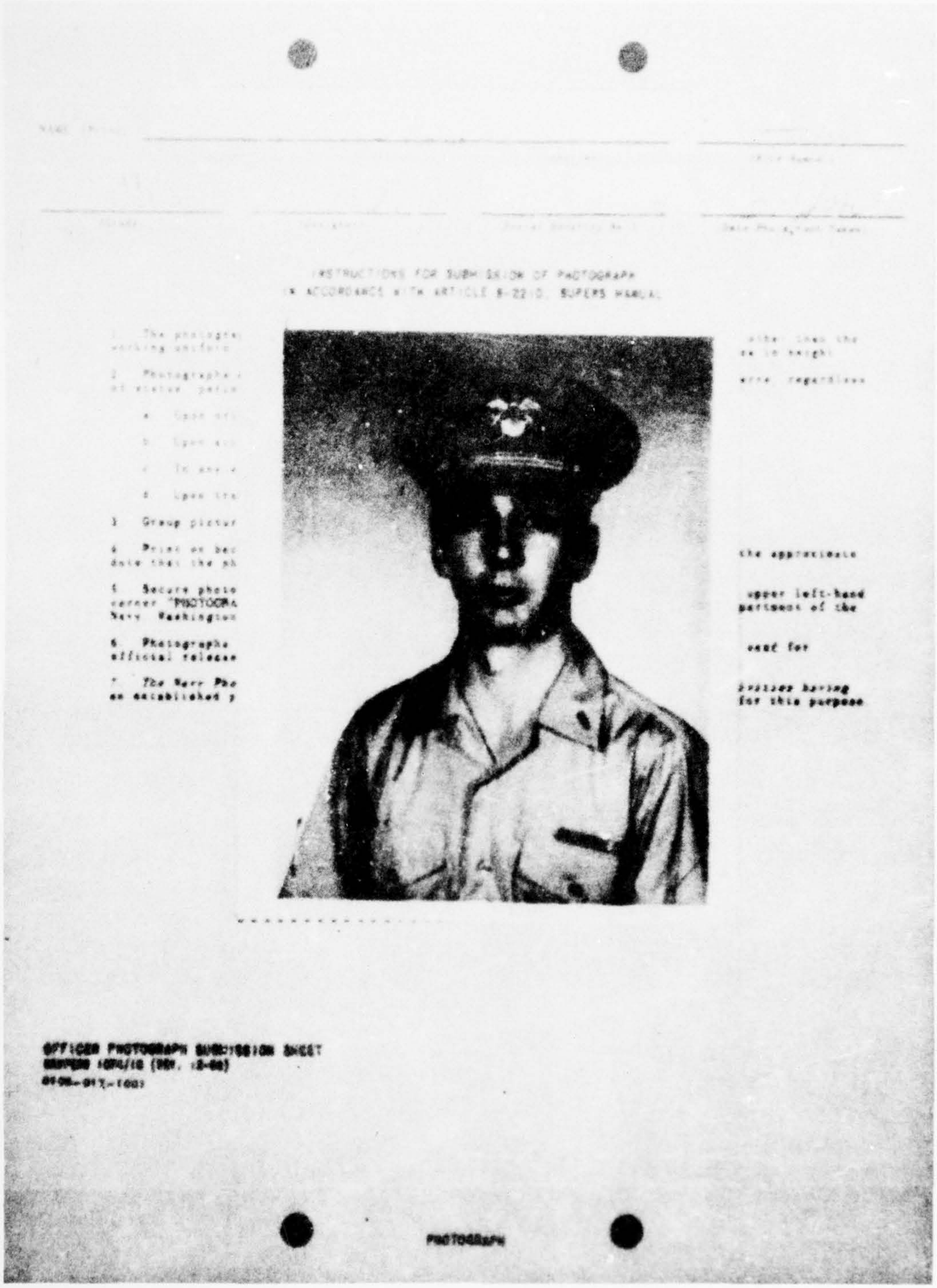
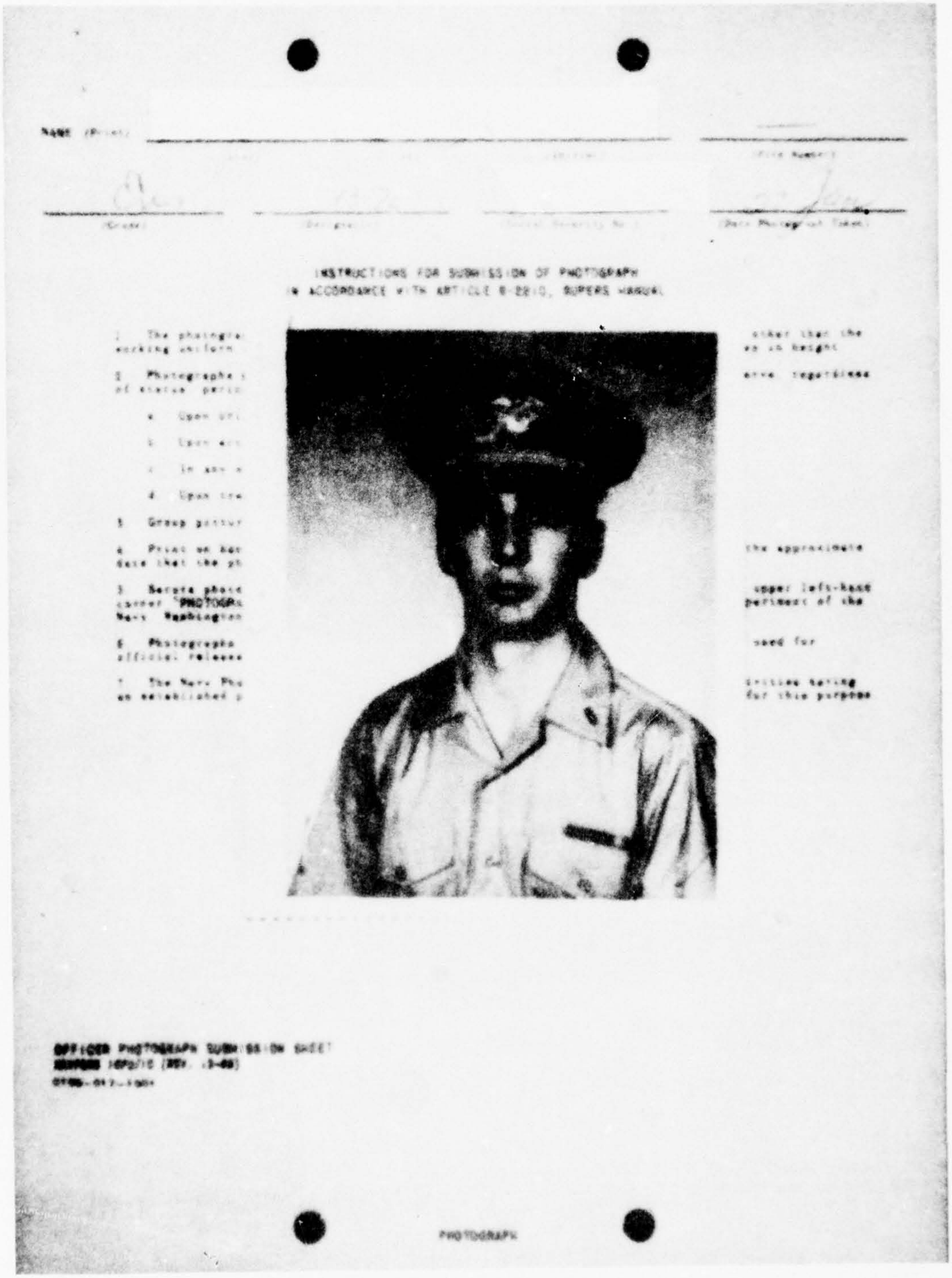


Figure 3.2. Officer photograph scanned at 8.3 facsimile lines per millimeter.
(Shown photo reduced)



INSTRUCTIONS FOR SUBMISSION OF PHOTOGRAPH
IN ACCORDANCE WITH ARTICLE B-2210, BUPERS MANUAL

OFFICER PHOTOGRAPH SUBMISSION SHEET

PHOTOGRAPH

Figure 3.3. Officer photograph scanned at 4.2 facsimile lines per millimeter.
(Shown photo reduced)

the scanned output microfiche images (including the sample images shown in Figures 3.2 and 3.3) in fiche readers. It should be noted that sample output images scanned at 6.3 lines per millimeter were not produced because there were no scanners available for experimentation which operated at precisely this resolution. The good correlation with the predictions for the samples which were produced, however, does support the recommended scanning resolution for MITS.

In conclusion, both theoretical and empirical research indicate that for legible reproduction of lower case, 6-point type, MITS facsimile resolution of 6.3 lines per millimeter (160 lines per inch) is required for full-size images. The corresponding resolution at which the BUPERS microfiche should be scanned is 151 lines per millimeter (3,840 lines per inch).

Scanner Requirements

The scanning device which converts the microfiche pictorial information into a digital data representation is the most complex and expensive component of MITS. The scanner must receive the BUPERS microfiche, transport and position the fiche between the scanning beam and the photodetector, convert the photographic images on the fiche to position-registered digital electrical signals, pass the digital signals to a data transmission link, and eject the scanned fiche. The complete scanner operation must be as automatically controlled as possible. Human interaction will be limited to loading fiche into the scanner, taking the scanned fiche from the scanner, and monitoring an operational status console. Routine cleaning and preventive maintenance will be performed during a 4-hour period each day when the scanner is not operating.

To help evaluate the different scanner options, the scanning requirements for MITS were compiled and are summarized in this section. One basic scanner function is to transmit light or an electron beam through the microfiche being scanned. The beam is deflected in a line-scanning pattern (raster) created by moving mirrors, prisms, or acousto-optical deflectors, and motion of the microfiche. The intensity of the beam transmitted through the microfiche is detected by a photosensor to generate a video signal. Thresholding devices convert this analog signal into a data stream of position-related digital data bits (ones and zeros) representing transparent and opaque picture elements (pixels). Thus, the scanner reads and encodes the photographic imagery in a serial digital data stream.

It has been shown that scanning can be performed on any transparent medium. Although scanning is conventionally performed on silver-halide film, the images on diazo film are sufficiently opaque for scanning. The practicability of laser scanning of diazo duplicates was demonstrated in a scanning test performed recently by NUC (Reference 3.2). A helium-neon (red) laser was employed to scan BUPERS diazo duplicates and to reconstruct a microfacsimile of the record on a silver-halide film.

To determine the effect of laser wavelength (color) on perceived contrast during scanning of BUPERS diazo duplicate microfiche, a set of controlled experiments was performed. Four different wavelengths in the blue and green ranges (argon ion laser) and one wavelength in the red range (helium-neon laser) were individually tested by passing the laser beam through various image regions of actual BUPERS diazo duplicates. The normalized relative contrasts between image area and substrate background were measured with a photomultiplier tube.

The results of this test indicate that there is no discernible change in apparent contrast when the laser wavelength is changed (Reference 3.3). For this reason, all visible laser wavelengths investigated are acceptable for a MITS scanner.

The standard off-the-shelf lasers currently used are the helium-neon (red) and the argon ion (blue-green). In addition, a helium-cadmium (blue) laser has been used, but its reliability is much lower and availability is much less. For reasons of low cost, high reliability, and excellent availability, helium-neon laser is recommended for a MITS-compatible laser scanner.

This study discovered that scanning technology is a mature technology. Laser scanners able to read aerial reconnaissance photography as well as reproduce it were developed over 10 years ago. Resolution requirements, scanning speeds, and dynamic range far in excess of the MITS requirements have been met by devices which are currently operating in the field. Based on the resolution requirements, fiche volume, and turnaround time requirements, the following summary of the MITS scanning requirements has been compiled (Table 3.3).

Table 3.3. MITS scanning requirements.

Scanning Resolution	151 picture elements (pixels) per millimeter (3,840 pixels per inch) and 151 scan lines per millimeter (3,840 lines per inch).
Equivalent Scanning Spot Size	6.6 micrometers.
Scan Target	BUPERS 24X reduced microfiche images of personnel records on diazo duplicate film.
Image Size	Each image is 10-mm (0.394-inch) wide by 12.5-mm (0.492-inch) high for image plus grid margin.
	The scanner will produce 2.9 X 10^6 pixels per image.
Image Format	Images are arranged in the standard microfiche format of 7 rows with 14 images per row.
	The microfiche size is 105 mm (4.13 inches) by 148 mm (5.83 inches) wide. An average BUPERS fiche has 25 images in a field of 98 locations.
Scan Rate	The system must scan 30,000 images (8.7 X 10^{10} pixels) per 20-hour operating day. This corresponds to 2.4 seconds per image to load, position, scan and eject the fiche to an output stack.
Data Output	One bit of digital signal representing either a black or white pixel. The average data rate is 3 X 10^6 bits per second.
	The maximum data rate will be 7.5 X 10^6 bits per second.

Scanner Review and Selection. This section describes the various options for the MITS scanner and includes a description of the different scanners and their respective advantages and disadvantages. Cost comparisons are included, but the tentative nature of the estimates from the various manufacturers underlies the fact that they must be considered estimates, not price tags. It is also important to note that the actual prices are being reduced as more applications are found for scanners and more are produced.

To summarize the findings, it was determined that the most acceptable state-of-the-art scanners which fulfill BUPERS volume and resolution requirements are those which use a spinning, multifaceted, polygonal mirror to deflect a laser beam through the film and detect the position-addressed light intensity with a photodetector. A less mechanically complicated, more reliable, and lower cost system will be available in the next 2 to 5 years which uses solid-state charge-coupled-device (CCD) line-sensing arrays.

The following types of scanners were surveyed and organized into two categories:

1. High-resolution scanners which meet the MITS resolution and speed requirements.
2. High-resolution scanners which do not meet the BUPERS speed requirements (Table 3.4). The seven high-speed scanners discussed in this report were the prime candidates for MITS.

Laser-Beam Spinning-Mirror Scanner. A laser beam deflected by a spinning polygonal or pyramidal mirror is the basis for the most promising scanner for MITS at this time. Spinning-mirror scanners have been built by several companies, including the Ampex, Goodyear, Harris, RCA, and Singer corporations (References 3.4, 3.5, 3.6, and 3.7 describe these systems). This scanner is the most widely selected for high-speed, high-resolution applications.

Table 3.4. Types of scanners surveyed.

High-Resolution, High-Speed	
	Laser beam deflected by spinning polygonal or pyramidal mirror
	Laser beam deflected by oscillating, galvanometer-driven flat mirror
	Flying spot cathode ray tube (CRT)
	Passive solid-state linear-array sensor using stationary light source
	Electron beam deflected on scintillating film
	Vidicon camera
	Image Dissector
High-Resolution, Low-Speed	
	Rotating cylinder, fixed-axial detector
	X-Y positionable flat bed with fixed spot

The principle of this scanner is illustrated in Figure 3.4. A laser beam is directed to the surface of the mirror, which rotates and causes the beam to be deflected along a linear path on the surface of the target film. A photodetector behind the film measures the image density and generates a signal proportional to film transmittance. The position of the mirror and the position of the film are encoded so that the electrical signal from the detector is position-addressed.

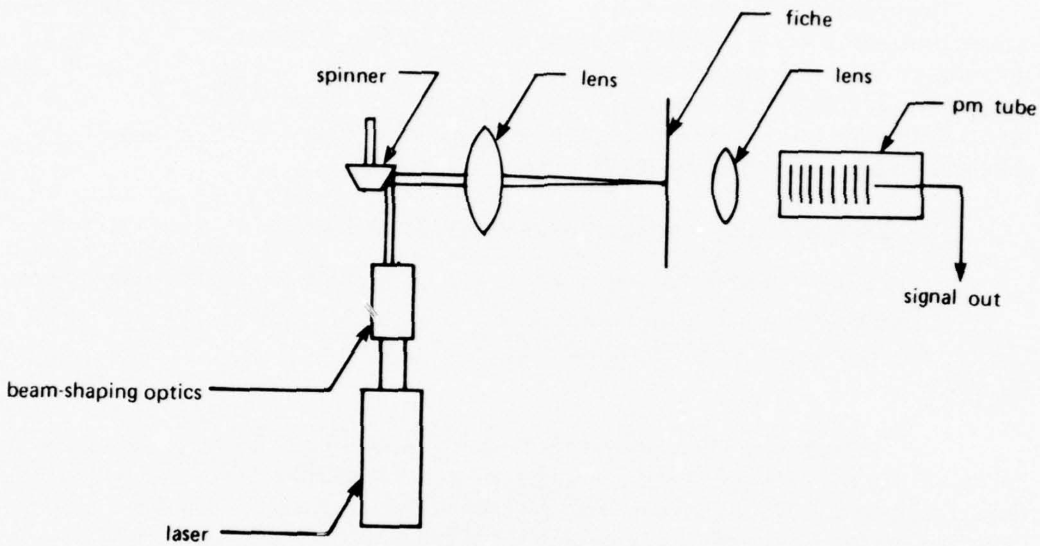


Figure 3.4. Laser spinning-mirror scanner.

Each company has built its scanner in various configurations depending upon the application and each has a proprietary technique that is emphasized. Ampex, Goodyear, and Harris all use field-flattening lenses to correct the cylindrically oriented focal plane to a flat linear format, hence allowing a flat film to be scanned. RCA and Singer curve the film into a cylindrical "canoe" shape and, therefore, eliminate the corrective optics. In each of these scanners, air-bearings support the motor shaft which drives the mirror. Each company has built multifaceted, polygonal mirrors and single and multifaceted pyramidal mirrors. The particular selection is usually based on experience with past applications and in-house designs. The control circuitry, thresholding circuitry (to convert the image density signal into a digital signal), data formatting, position encoding and all of the necessary components are included in these essentially stand-alone devices. They take a film input and produce an encoded serial digital data stream.

There are several configurational options for the MITS spinning-mirror scanner. Harris is the only company which has an off-the-shelf design for a fiche-format, flat-bed positioner coupled with the spinning mirror technique. This design is currently being installed in a second-generation version of the human-readable, machine-readable (HRMR) microfiche system, a system under development for Rome Air Development Center (RADC). The positioner is coupled with an automatic stack loader and ejection system. A transporter delivers the fiche to a vacuum platen which positions the fiche at a controlled velocity in the vertical or Y-direction, while the mirror deflects the beam along the horizontal or X-direction. In this way, each image can be scanned independently.

The Ampex, Goodyear, and RCA designs all use roll film transports, since their recorders were developed primarily for photographic interpretation by the reconnaissance community. These scanners now scan an entire film width in excess of the 105 mm (4.13 inches) required for MITS and advance the film longitudinally while the beam traverses the film. This corresponds to scanning along a complete column or row of a fiche at one time, depending on the orientation of the fiche images on the roll of film. The design of a flat-bed transport to adapt these systems to the MITS needs for an image-by-image scan would require an additional expenditure of nonrecurring funds. However, this is not expected to be a high-risk design effort.

Spinning-mirror scanners are inherently reliable, with the spinner assembly capable of operating continuously for several years without detectable wear or deterioration. The most complex mechanical element in these scanners is the film transport mechanism. Considerable development to provide reliable transports has already been undertaken by the companies mentioned above. In addition, Goodyear, RCA, and Ampex have built these scanners in the recorder configuration for airborne applications, so that reliability even under severe environmental conditions has been demonstrated.

Laser-Beam Galvanometer Scanner. A scanner based on a laser beam deflected by an oscillating, galvanometer-mounted mirror is a high-resolution device with intermediate scanning speed capability. This type of scanner is a lower-speed and lower-cost device than the spinning-mirror scanner. It can be built by a few companies, including Ampex, Bell Telephone Laboratories, and Harris, but no off-the-shelf units are available.

The principle is illustrated in Figure 3.5. The scanning technique is similar to that of the spinning-mirror scanner. The oscillating mirror deflects a laser beam to trace a line across the target film, and the intensity of the transmitted light is detected with a photodetector situated behind the film. As with spinning mirror scanners, single fiche and roll film are the input options.

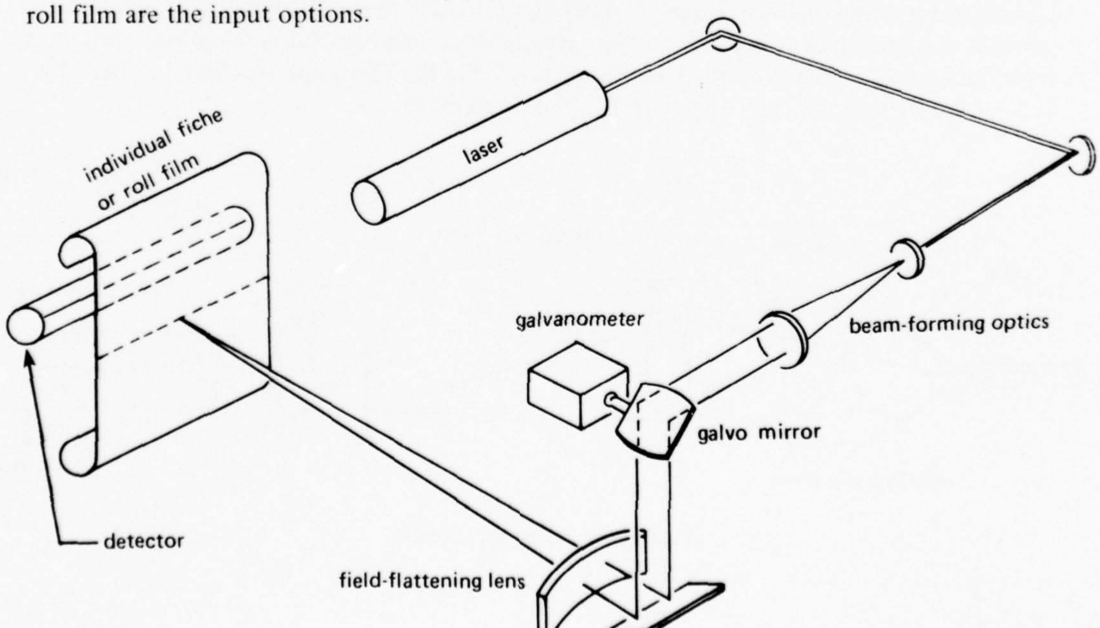


Figure 3.5. Galvanometer scanner.

The characteristics of galvanometer scanners include relatively slow operation resulting from inertia effects as the mirror is accelerated during each oscillation, nonlinear sweep velocity, nonconstant focal length, and a relatively short galvanometer bearing life. The galvanometer life decreases as the oscillating frequency and the mirror size increase. Even though the Ampex and Harris Corporations both build galvanometer scanners, their engineers indicate that the MITS scanning speed and aperture requirements for roll film scanning dictate a galvanometer scanner configuration which would be cumbersome and unreliable. A more practical option is a single-image scanner with an X-Y positioner for the fiche. Unfortunately, achieving adequate scanning speeds may seriously degrade system lifetime. However, the galvanometer scanner seems to be most suitable for low-speed, low-volume facsimile systems operated manually or semiautomatically.

A single-fiche scanner has been built by the Bell Telephone Laboratories. It used a high-speed galvanometer to sweep the horizontal lines and a low-speed galvanometer to increment the scan from line to line. This relatively low-cost system performs an image scan in 4 seconds, but the loading and positioning operations are manual. Only one prototype has been built, and Bell has not pursued the effort. They may be interested in building another, however, when MITS reaches the specification phase. Reference 3.8 is a report on this system.

Flying Spot Scanner. Flying spot scanner technology has been available for several years. This is one of the fastest types of scanners, primarily because the scanning is accomplished electronically, not mechanically.

A flying spot scanner is illustrated in Figure 3.6. A CRT is used to create the raster-scanning pattern with the electron beam illuminating the screen phosphors. The light emitted from the phosphors is focused onto the fiche. The intensity of the transmitted light is then detected by a photodetector placed behind the film. The engineering difficulties include maintaining small spot size, controlling spot color to match the target film characteristics, minimizing the persistence of the phosphor emission so the moving spot does not generate a streak across the CRT face, and maximizing the phosphor efficiency so that the transmitted light intensity is sufficient for photodetection.

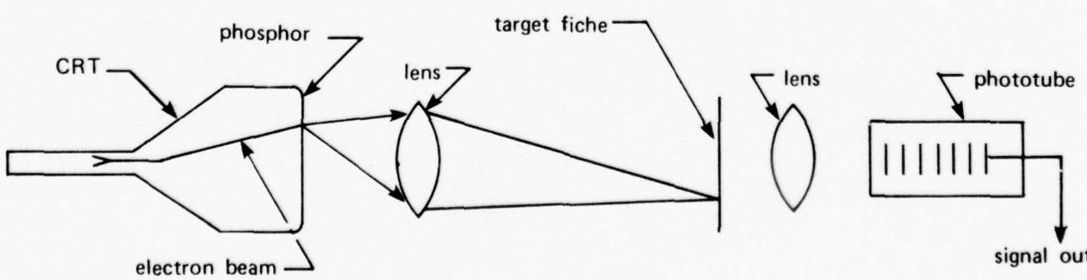


Figure 3.6. Flying spot scanner.

An EPSCO Labs study indicates that a flying spot scanner can be built to achieve 236 lines per meter (6,000 lines per inch) resolution at about 6 seconds per page scan (Reference 3.9). This is a higher resolution but lower speed than MITS requires. The differences in speed can be overcome, but the engineering techniques for accomplishing this are not trivial and require sophisticated control circuitry. In the study's recommendations for a microfiche scanner, it was noted that a flying spot scanner would cost more than either a laser scanner or a solid-state scanner. In addition, the flying spot scanner was found to have the highest failure rate of the scanners reviewed, primarily due to the complexity associated with the CRT electronics.

The scanner survey revealed no available off-the-shelf microfiche CRT flying spot scanners. Although such a scanner could be built, it is not recommended for the MITS because of the difficulties and disadvantages mentioned above.

Solid-State Scanner. A promising device for scanning the MITS fiche, which will be available in the future, is a solid-state scanner which uses CCD linear arrays. This fixed-array technique is illustrated in Figure 3.7. This scanner uses a passive sensing array to detect the film density immediately in front of each array element. The only motion required is to pass the fiche between the array and a light source at a controlled speed. This technique promises to make possible a very high reliability in a very low-cost, easily-maintained scanner.

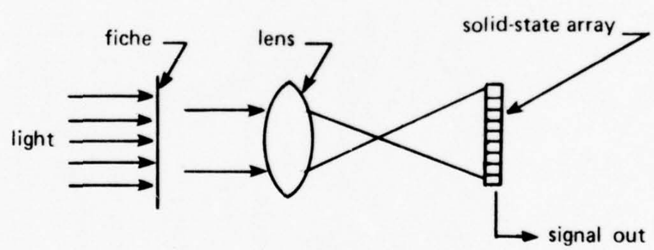


Figure 3.7. Solid-state scanner.

Although an operational version of such a scanner for microfacsimile has not yet been built, researchers at the Naval Electronics Laboratory Center (NELC) are experimentally using Fairchild CCDs to scan opaque images on paper (Reference 3.10). A commercially available, 1,728-element CCD array which has enough elements to register the 1,510 pixels along the width of a microfiche image is produced by the Fairchild Corporation. A scanning device can be built which dedicates one CCD array to each column of the fiche. One such configuration of this scanner is shown in Figure 3.8. The fiche is transported over the sensors while being back-illuminated from a stationary light source. The only moving part of this system is the film transport, which can be either a fiche or a roll film transport. Reliability should be quite high. The review of scanning equipment for a microfiche remote display system performed by EPSCO Labs for RADC (Reference 3.9) concluded that a solid-state scanner would be the least expensive to procure and operate, and that it would also be the most reliable.

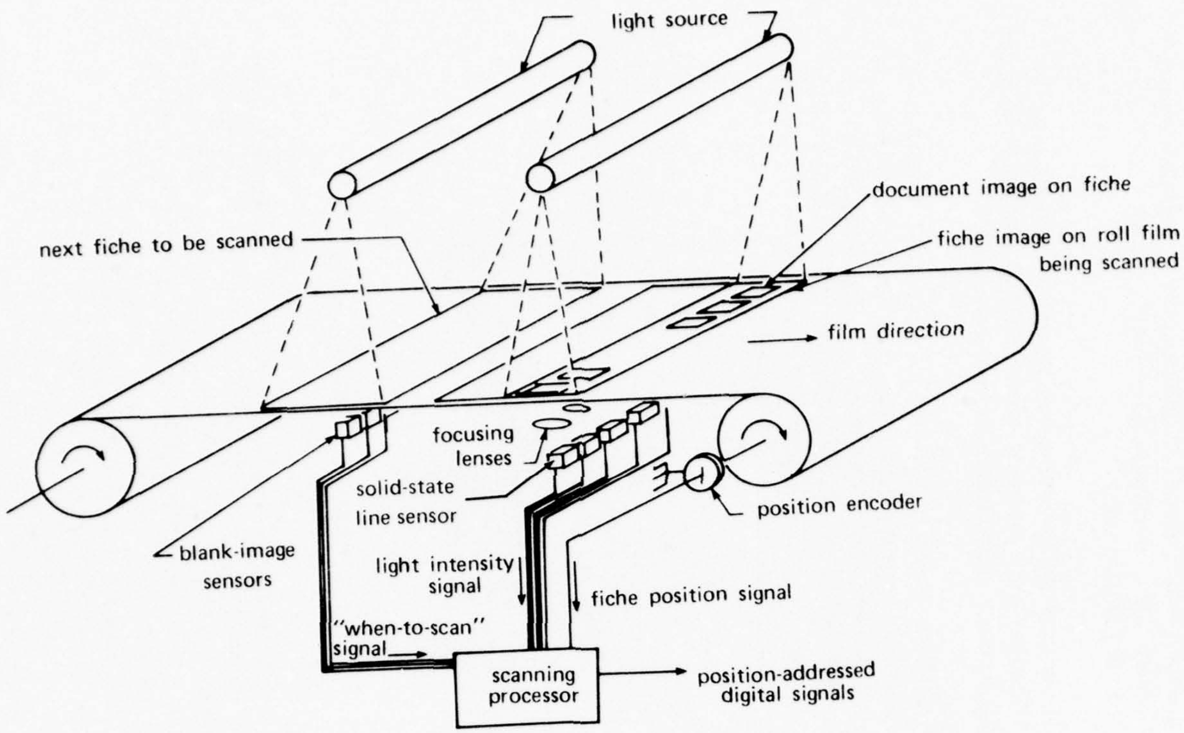


Figure 3.8. MITS solid-state scanner.

An additional feature which will allow purging of unwanted images is a blank-image sensing array over which the fiche passes immediately prior to passing over the scanning array. This grid could sense blank images, and, through the scanner controller, de-activate the appropriate sensor. In this way, an efficient means of producing data for the filled images only is provided. In fact, CCDs or similar overall image-sensing devices could be coupled to any type of scanner (spinning mirror, galvanometer, CCD) selected for MITS to provide a means of skipping all of the nonimage area of the input fiche.

Although no company has yet built an operational solid-state microfiche scanner, RCA is actively pursuing the technique. In addition, the U.S. Postal Service is supporting high-speed paper facsimile development efforts at NELC wherein CCDs are used (Reference 3.10). Several other companies are funding exploratory development work in their research sections with the objective of implementing a solid-state scanner. Within a year or two, a solid-state microfiche scanner may be available. Although no costs for this system have been quoted, it is anticipated that a scanner capable of handling the MITS volume would cost significantly less than the spinning-mirror scanner and possibly less than the galvanometer scanner. It is highly recommended that a solid-state scanner be developed for microfacsimile and that a near-future MITS should be based on this type of scanner.

Electron Beam Deflected on a Scintillating Film. The electron-beam approach for scanning is based on deflecting an electron beam in a raster-scanning mode. As shown in Figure 3.9, the beam is passed through the target microfiche and onto a specially-coated film. The scintillating film reemits a quantity of photons proportional to the target density and these are detected by a photodetector. Technical representatives of Image Graphics, Incorporated, a company specializing in electron beam recorders, have suggested this technique is possible, but that no scanners have been built to date. Although high speeds are possible with the electron-deflection approach, the uncertainties in development, the potentially high equipment and maintenance costs, and the very limited availability of the special scintillating film are such significant disadvantages that this approach is not recommended.

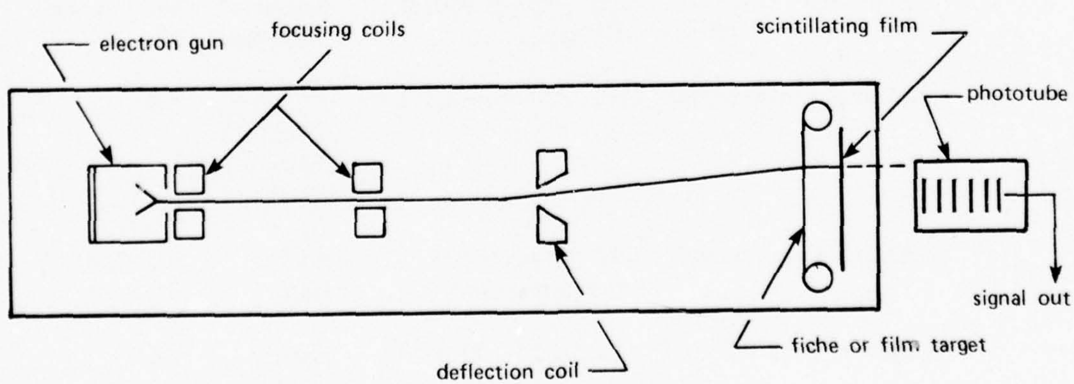


Figure 3.9. Electron-beam scanner.

Vidicon Camera and Image Dissector Scanners. The vidicon camera and image dissector scanners will only be mentioned briefly since they are not acceptable for MITS. A vidicon camera scanner uses a photoconductive target and a low-energy electron "read" beam. The image dissector uses back-illumination of the target fiche to image onto the photocathode of an image dissector. The number of electrons reaching the electron multiplier is a function of the illumination and, hence, the density of the target. Both of these scanners exhibit very low signal-to-noise ratio and are therefore judged unacceptable for MITS. A more complete description of these scanners is available in Reference 3.9.

Conclusions and Recommendations. In conclusion, there are several existing techniques for scanning and digitizing microfiche at the resolution and speed required for MITS. They are, in order of preference:

1. Solid-state scanner
2. Spinning mirror, deflected laser scanner
3. Oscillating mirror, deflected laser scanner (galvanometer driven)
4. Flying spot CRT scanner.

The characteristics for MITS-compatible versions of each are summarized in Table 3.5.

The solid-state scanner is not a proven design since no company has built a solid-state microfiche scanner. For this reason, it can only be considered a future option. On the other hand, spinning-mirror scanners are available from at least four companies: RCA, Harris, Goodyear, and Ampex. These scanners are built to customer specifications, so the MITS requirement can be incorporated from the beginning of construction. The cost is tentatively estimated to be $300,000 each. Since none of the proprietary design differences are

Table 3.5 Scanner selection summary.

Choice	Type	Speed	Source	Relative Cost[1]
1	Solid State	10×10^6 pixels/sec 3.4 image/sec	Not yet available	Not yet available
2	Laser Spinning Mirror	15×10^6 pixels/sec 5.2 image/sec	RCA Goodyear Ampex Harris	1.0
3	Laser Galvanometer	1×6^6 pixels/sec 0.34 image/sec	AT&T Harris	0.2 - 0.6
4	Flying Spot CRT	10×10^6 - 20×10^6 pixels/sec 3.4 - 6.8 image/sec	Litton provides tubes)	1.2

[1] Based on laser spinning mirror scanner cost = 1.0.

significant, the procurement can be made only after competitive bidding by the manufacturers. The galvanometer scanners are individually too slow for MITS, so two are required. Discussions with the vendors indicate probable difficulties with wear and deterioration of the galvanometers. Since the cost for two of these nearly equals the cost of a single spinning mirror scanner while the reliability is lower, and because no galvanometer scanners for microfiche are commercially marketed, this option is not recommended for MITS. Similarly rejected is the flying spot CRT scanner, in this case, because of the electronic circuitry complexity, high cost, and uncertain maximum speed capability.

Thus, the laser-beam spinning-mirror scanner is recommended for the MITS at the current time.

Automatic Fiche Handling

The purpose of the MITS automatic handling subsystem is to feed and transport microfiche duplicates into the scanning device automatically. The microfiche to be input to the scanner must be retrieved from the BUPERS master file and manually duplicated on diazo film, and the diazo copy is then loaded into the scanner. Within the scanner, the fiche are sequentially delivered to the scanning aperture, x-y positioned, and then returned to an output bin.

A survey of available fiche delivery systems yielded one system which could sequentially feed individual standard NMA microfiche. This system was designed and constructed for the Rome Air Development Center human-readable, machine-readable microfiche system. Figure 3.10 illustrates the system. The transport commences with loading a stack of microfiche horizontally into a bin. On command, a vacuum retrieval arm extracts the bottom fiche from the stack, reverses pressure, and ejects the fiche into a transport guide. Successive capstan drive wheels transport the fiche along a track until they reach an X-Y platen. Here, the upper edge of the fiche is drawn to the platen by vacuum. A high-speed, high-precision servomotor controls the x-y positioning platen. This platen is then programmed to orient the fiche over any image grid desired. Scanning of this image-size aperture can then take place.

This entire load, transport, and x-y positioning system has been designed and constructed for the HRMR system. The design is modular, such that the retrieval subsystem, the transporter, and the x-y platen could be applied to a variety of scanners. It has been mated successfully to a spinning-mirror scanner by the Harris Corporation on the production model of the HRMR. The estimated cost for duplicate versions of the handling system is $60,000 each. The reliability is considered to be high due to the relatively simple transport mechanism and high-quality servomotor control of the X-Y platen.

An alternative means of providing automatic loading and transport of the microfiche is to input them as microfiche images on roll film, as noted in the scanner section. This option uses the duplicator which produces the duplicate diazo fiche from the master fiche in the BUPERS file. A cutting override is recommended so that rolls of fiche images are generated rather than individual fiche. When appropriate lengths of film are recorded in the duplicator, a cut can be made and the roll inputted to the scanner. Thus, the existing roll-film transports in the scanners can be used. To take advantage of the best scan direction for data compression, the fiche should be oriented as noted in Figure 3.11. This can be readily

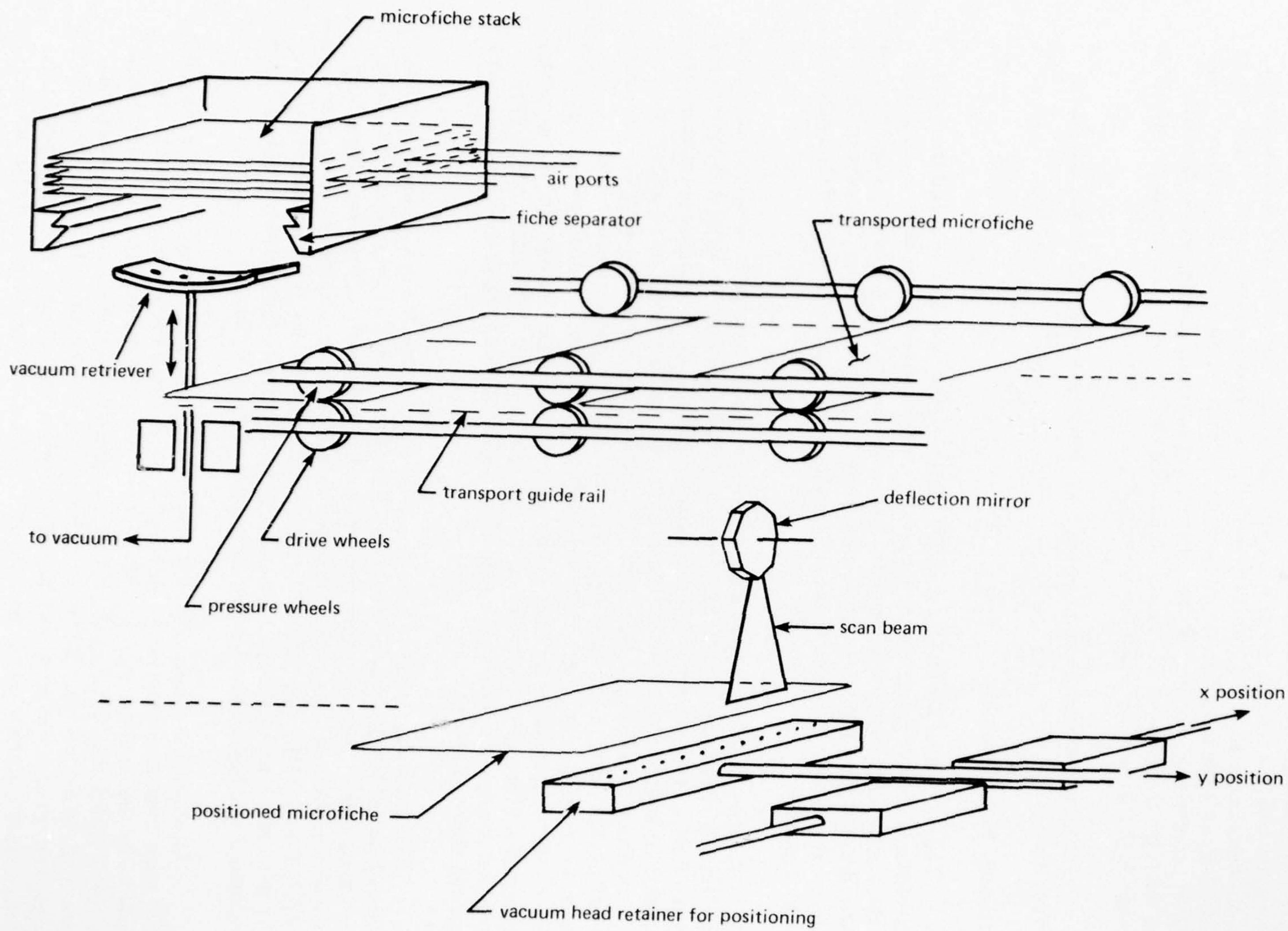


Figure 3.10. HRMR loader-transporter-positioner.

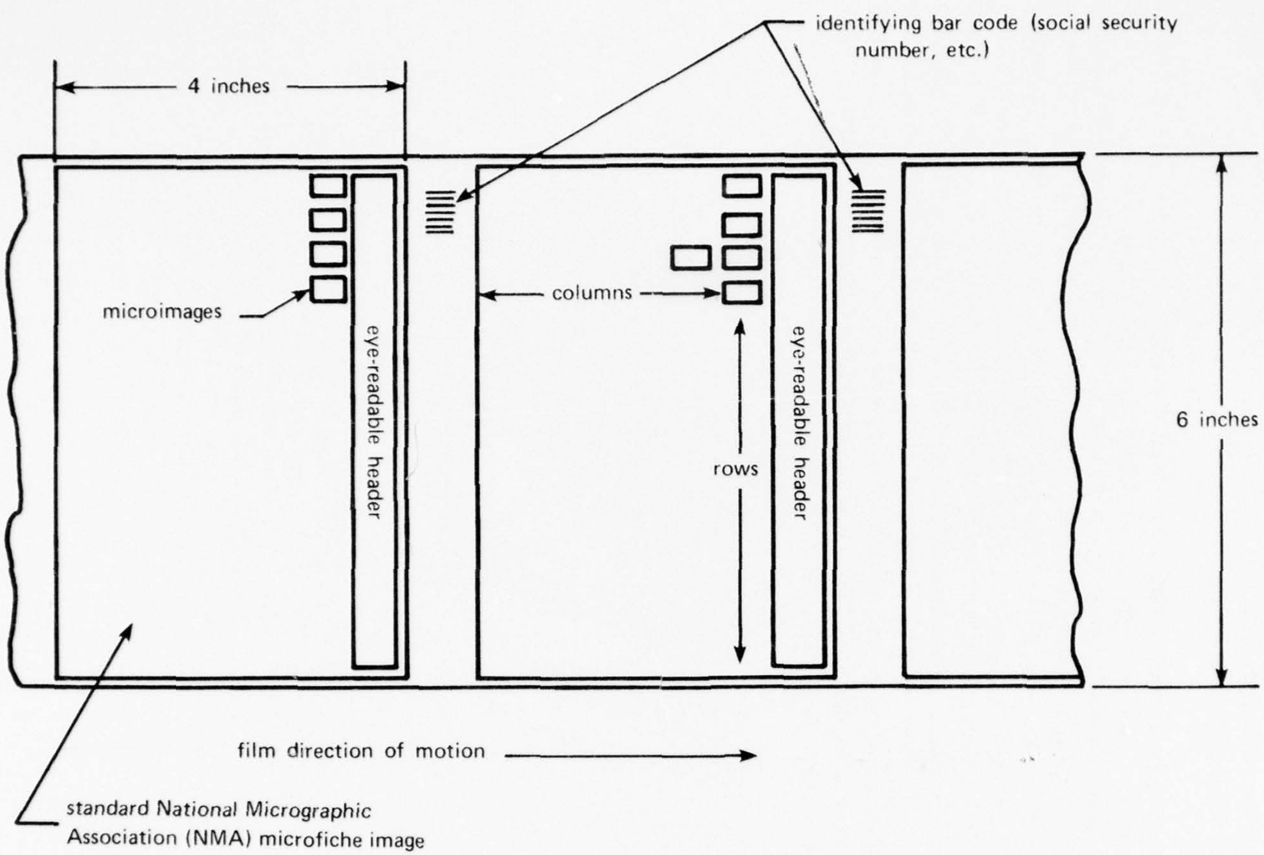


Figure 3.11. Fiche image orientation.

accomplished by rotating the duplicating platen and using a 6-inch wide diazo film. Both features can be incorporated in standard duplicators built by GAF Corporation and others. There is no extra charge for the 6-inch wide diazo film, so standard duplicating film costs apply. An encoding function could also be added to the duplicator to denote to the scanner the beginning of record, social security number, and end of record, thus providing a means for maintaining record order and inventory. A simple machine-readable (by the scanner) bar code can be employed for encoding.

In summary, two basic options are available for automatically loading, transporting, and positioning microfiche. First, an off-the-shelf design of a reliable stack feeder, roller transport, vacuum platen, servo-driven X-Y positioner, and return-to-bin system exists. This system can be readily coupled to a variety of scanners for approximately $60,000 each. Second, an option is to modify a standard off-the-shelf diazo duplicator to produce encoded, 6-inch wide rolls of fiche images. The cost for a modified duplicator is estimated to be $35,000. This option provides an improved document control and inventory method during the transmission cycle. The disadvantage is that this can only be used with roll film scanners (laser spinning mirror) which have standard off-the-shelf film transport designs. These are not recommended if image-packed output microfiche are to be transmitted. Therefore, the HRMR system is recommended for automatically loading, transporting, and positioning the diazo duplicates in the scanner recommended in the previous section of this report.

OUTPUT CONSIDERATIONS

Recorder Selection

The function of the MITS recorder is to transform the incoming and appropriately organized digital data stream from the transmission link and reconstruct the microimages on microfiche at the remote sites. Under current BUPERS requirements, the output device must produce 1,200 fiche per day. As noted in the scanner section, the microimages will be represented by 2.9-million bits at a resolution of 151 pixels per millimeter (3,840 pixels per inch) by 151 lines per millimeter (3,840 lines per inch). The recorder must operate at the same speed as the image-by-image input scanner, an average rate of 3.0×10^6 pixels per second. (Actual writing speed will reach 7.5×10^6 bits per second as noted in the design section of this report.) The output will have the same resolution as that specified for the scanner.

A survey of recorder manufacturers resulted in discovery of three types of recorders which can potentially fulfill the requirements for the MITS recorder. They include the following:

1. Laser beam recorder (LBR)
2. Electron beam recorder (EBR)
3. Cathode ray tube (CRT) recorder.

Laser-Beam Recorder (LBR). The LBR is actually a form of the laser spinning-mirror scanner. The difference is in the addition of a laser beam intensity modulator to vary the exposure of the output film according to the incoming digital transmission. The basic layout is illustrated in Figure 3.12.

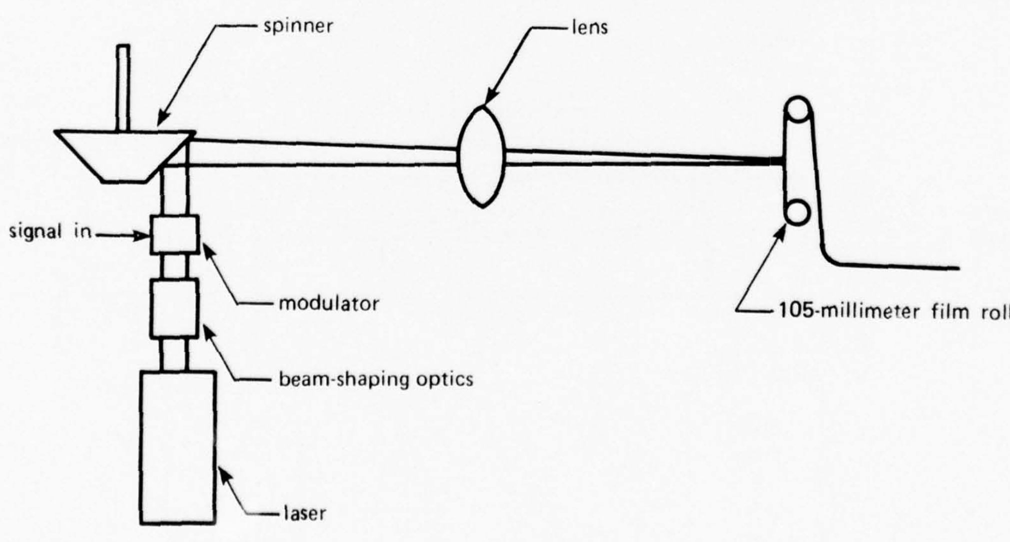


Figure 3.12. Laser-beam recorder.

LBRs are very high-speed, high-resolution devices. They have been designed to attain 1 micrometer spot size (1000 lines per millimeter or 25,000 lines per inch) and operate at speeds well in excess of 20 million bits per second. Four companies were discovered marketing raster scanning LBRs: Ampex, Goodyear Aerospace, Harris, and RCA.

To accommodate image-packed output microfiche, the recorder must write line by line across an image rather than write line by line across an entire fiche. Thus an x-y positioner is necessary to orient the fiche image by image. The Harris HRMR system verifier is an existing LBR with an x-y positioner. Although the LBRs from the other three companies currently write across the entire film width, implementation of an x-y positioner will be straightforward. In fact, since the input scanner must also have an x-y positioner and with the system recommendation of an input laser beam scanner, the recorder can be a duplicate of the scanner with the appropriate writing features. Thus, the engineering costs need only be paid once. The resulting system will also have a two-way transmission capability, since the devices can operate as either scanners or recorders.

Assuming that a duplicate scanner-recorder will be purchased from the same company for each end of MITS, the estimated cost of the recorder is $200,000. The cost is dependent on combined bids being received for both items. If only the recorder is purchased, the cost will be closer to $300,000. For reasons of system redundancy, high resolution, and high writing speed, an x-y positioning LBR is recommended for MITS.

Electron-Beam Recorder (EBR). The principle of the EBR is the generation of a focused beam of electrons that are deflected in a line-scanning mode by electronically controlled yokes. The electron beam intensity is modulated to match the incoming digital signal, and this modulated beam is scanned across a 105-millimeter roll film specially prepared for electron beam sensitivity. This film must be kept in an evacuated chamber. The recorder configuration is shown in Figure 3.13. It is noted that the film for the EBR has only been produced by Kodak in small amounts for experimental use. It is not commercially available at this time.

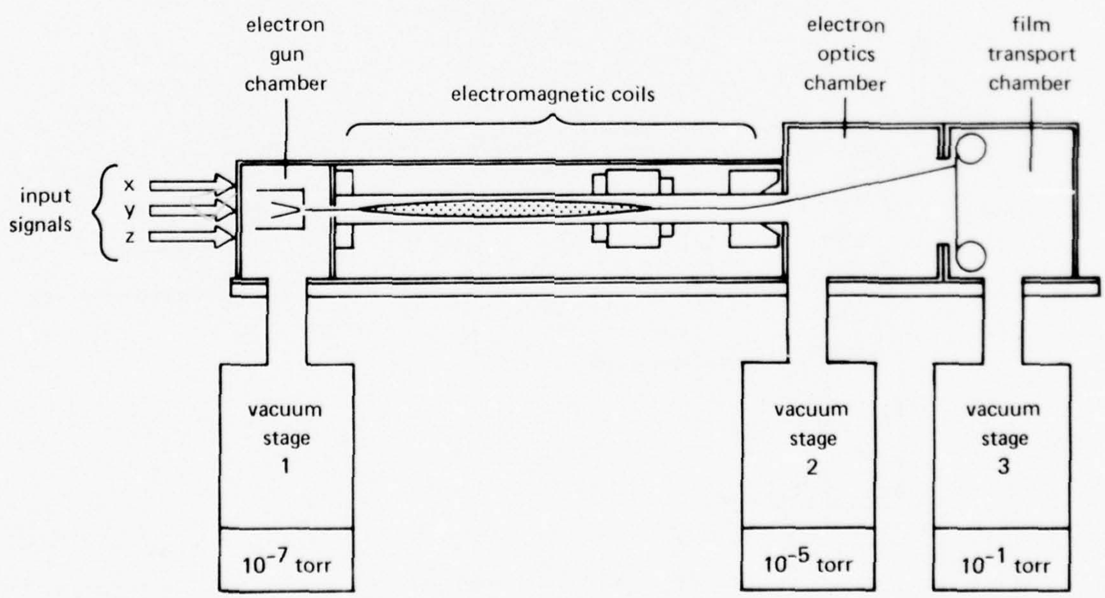
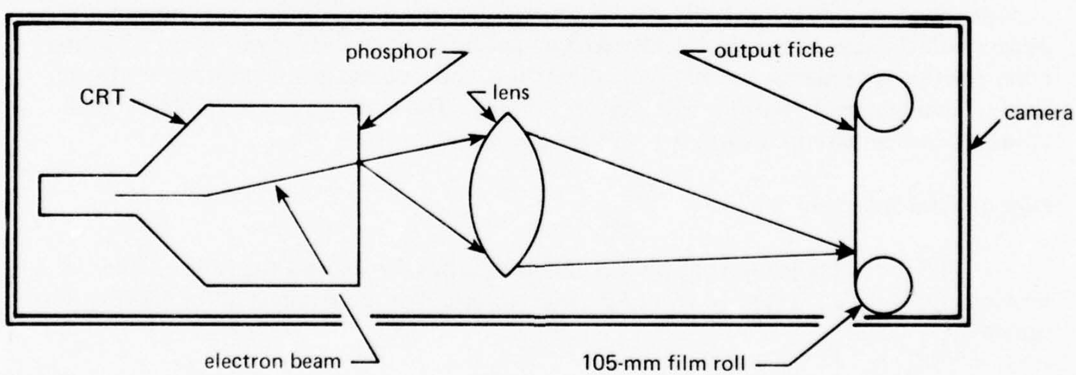


Figure 3.13. Electron-beam recorder.

The EBR can be modified to meet the MITS requirements. It requires minor factory software changes and removal of some of the optional components. However, the EBR does write on the entire 105- by 148-millimeter fiche rather than step the film from image-to-image. Hence, the raster must contain 17,850 lines with 25,500 pixels per line, easily accomplished with existing EBRs.

The major advantage of an EBR is a high throughput capability, up to 20 micro-images per second, and minimal mechanical complexity. This is because the beam deflection is performed electronically. The disadvantages include complex electronics, maintenance of the vacuum system, and uncertain price and availability of the recording film. This recorder can fulfill MITS requirements, and it is capable of much higher speeds. It can also record image-by-image or an entire fiche. This recorder is rated a second choice for the MITS output recorder, primarily because of the required "productization" for handling the microfiche format and the uncertainty as to the availability and cost of the special electron-sensitive film.

Cathode Ray Tube (CRT) Recorder. Most CRT recorders are available as computer output microfilm (COM) recorders. A high-resolution graphics COM recorder can potentially be modified to meet the MITS requirements. The graphics COM recorder is very closely related to the flying spot CRT scanner described in the scanner section. In the recorder version, the image is raster-recorded onto a CRT screen, and a camera records the image on roll film that is 105-millimeters (4.13-inches) wide. This camera positions the images on the film in the X and the Y directions to generate a microfiche format output. The principle is illustrated in Figure 3.14.



Figue 3.14. CRT COM recorder.

A list of COM recorder manufacturers was obtained from the NMA. These manufacturers were all contacted to determine whether they offered a graphics COM recorder. Only four manufacturers currently sell graphics COM recorders: 3M, CalComp, Information International, and Applicon. Datagraphix, formerly the major manufacturer of graphics COM recorders, has stopped production of their graphics COM recorders, and does not intend to reenter the market in the near future.

The advantages of a graphics CRT COM recorder include low initial cost ($120,000 to $200,000), off-the-shelf availability, and cameras which perform the x-y positioning to recreate standard format microfiche. The disadvantages include relatively slow speed (200,000 to 400,000 points/sec) and a limited selection of output film since only wet-processed silver-halide film is sensitive enough for the CRT screen phosphors to expose.

The speed limitations of the standard CRT COMS are the result of (1) standard magnetic tape drive input speeds and (2) the latency time required for the CRT beam to expose the film. The first limitation is readily overcome by eliminating the tape input and coupling the COM directly to an input source, such as the MITS receive buffer. COM recorder minicomputer controllers can easily accept the MITS data rates. The CRT speed limitations are more difficult to overcome. The scanning spot is limited to speeds which are not so fast that phosphor latency blurs adjacent pixels. At the MITS data rates, this image blurring is a problem.

The CRT COM has an addressability feature, such that only the pixels which must be exposed need be "addressed." This is different from the laser recording technique of addressing all points sequentially. Thus, a much smaller number of points can be addressed with the CRT (i.e., only the pixels corresponding to black type on the white background) and a lower average writing speed is possible. However, the extra data which must be included to define the addresses of the pixels ("x" and "y" position within the image) may well increase the overall data rate and add the complexity of entering the additional data. Since a CRT COM has not been demonstrated which will record at the required MITS data rate, this device is not recommended at this time.

Recorder Selection Summary. The options for an off-the-shelf MITS output recorder are summarized in Table 3.6. For reasons of good availability, redundancy of design with the input scanner, high speed, compatibility with a variety of films, and capability for two-way microfacsimile communication, the recommended recorder is a laser beam spinning mirror recorder with x-y positioning. The final selection should be made based on competitive bids from the four producers.

Output Film Selection

The following paragraphs discuss film properties, types, and the type of film recommended for each type of recorder. The specific film recommended for MITS is also noted.

Film Properties. MITS will use a large quantity of film at each remote site, perhaps up to 80,000 fiche per year at a site such as San Diego. This quantity represents a significant recurring cost, and thus, the selection of the film must be based on cost-to-procure and cost-to-process as well as on a matching of film and recorder characteristics. To select an output film, it is necessary to specify two major parameters: resolution and speed. These parameters will be discussed in this section and a general film recommendation will be made.

The MITS scanning resolution is 151 lines per millimeter with 151 pixels per millimeter. The most desirable film resolution capability is exactly 151 lines per millimeter at the recorder contrast value. A resolution of less than 151 lines per millimeter will result in lines of the output copy which are slightly too wide, while a resolution of more than 151 lines per millimeter may result in low-contrast lines that consist of small dots.

Table 3.6. MITS recorder options.

Type	Manufacturer (Model)	Speed	Cost
LBR	Ampex (special)	$>10 \times 10^6$ point/sec	1.7*
	Goodyear (Laser Recorder)		
	Harris (HRMR Verifier)		
	RCA (LR-71)		
EBR	Image Graphics (EBR-2000)	$>10 \times 10^6$ point/sec	1.3
CRT COM	3M (Beta 700)	$>0.2 \times 10^6$ point/sec	1.0
	Cal Comp (1675)	$>0.4 \times 10^6$ point/sec	1.3
	Information International (FR80)	Not available	1.7
	Applicon (AP75)	Not available	1.7

*NOTE: Cost predicated on design-duplication costs and MITS format modification costs paid one-time during scanner acquisition.

However, determining the actual film resolution in a particular application is not simple. It is necessary to specify the contrast between the light intensity which will fall on a line and the light intensity which will fall on the background spaces. This contrast ratio varies with different recorder settings, and it cannot be easily measured. Typical film resolution specifications are given for contrasts of 1.6:1, 6:1, and 1,000:1. A contrast value of 1,000:1 for all the MITS candidate records has been assumed, since they all have high contrast, usually white letters on a dark background. Based on these considerations, the recommended film resolution is 151 lpm at a contrast value near 1,000:1.

The film speed parameter is primarily a function of the recorder writing rate. The system throughput or writing rate is about 3,000,000 pixels per second. It must operate at this speed because the recorder addresses each pixel sequentially. COM recorders and EBRs can address points randomly and thus can skip image background areas. By only recording the pixels corresponding to text, these recorders can write at a slower speed while still maintaining the system throughput.

Film speed is defined as the reciprocal of the amount of light energy required to expose the film to a shade of gray. The film speed is a function of the exposure time, the wavelength of the light source, and the processing as it affects the background "fog level" or gray shade. In addition to affecting the film speed, the processing will affect the contrast. The processing technique will have a characteristic minimum fog level for the developed unexposed film and a maximum fog level for the developed exposed film. The ratio of these two fog levels is the maximum attainable output film contrast. The output film contrast will depend on the exposure intensity and the maximum attainable contrast.

All of these parameters, film resolution, film speed, and maximum contrast must be matched to the output recorder, the system throughput, and the output image quality requirements. The following section will discuss the available film types and recommend paraticular types for the three candidate recorders.

Film Types. There are three types of film under consideration for use in MITS:

1. Silver halide (wet processed)
2. Dry silver
3. Vesicular.

Silver halide is the conventional film which has been in use for over a century, while the other two are recent developments. Silver-halide film is available in a variety of film speeds and film resolutions. There are many ways to develop silver-halide film, all requiring processing in liquid chemicals. It should be noted that the exposure-light intensity relationship and the maximum contrast are controlled by the development. Silver-halide film can be either negative or reversal depending on the processing chosen. Dry-silver film is a variation of silver-halide film which was designed to be developed by heat only.

Vesicular films are based on an entirely different process. Gas bubbles are formed when the film is exposed to a light source. The bubbles are permanently fixed by heat and then viewed through rear projection viewers. Vesicular film contrast depends on the f-number (focal length of the lens divided by the lens diameter) of the viewer lens. It is the relative ease of processing that generates interest in dry-silver and vesicular films, since their photographic capabilities are inferior to conventional silver-halide film.

The film used for MITS must be matched to the recorder selected. The following paragraphs discuss these recorder-film matchings. Data sheets on the various films discussed can be found in Reference 3.11.

Film for CRT Recorders. A CRT recorder would use a CRT with a P-11 phosphor light source. Most COM recorder manufacturers recommend Kodak Dacomatic A wet-silver film for low- to medium-resolution requirements and Kodak Dacomatic E wet-silver film for high resolution requirements. Agfa-Gevaert and DuPont make film which is similar to Dacomatic A. These films all match the P-11 phosphor characteristics. The MITS requirements appear to be on the borderline between medium and high film resolution. It should be noted that the CRT phosphor intensity is not sufficient to expose dry-silver or vesicular films in a high-speed recording application such as MITS.

Film for Electron Beam Recording. The electron beam recorder can write on virtually any type of silver-halide film. A single electron can expose at least six silver-halide grains directly. Consequently, if high resolution is required, the silver-halide grains must be tightly packed. This requirement for high-grain density and a requirement for a thin emulsion can only be fulfilled with several specially prepared films available from Kodak. Kodak SO 438 film is especially designed for EBRs and is recommended as the output film for this particular recorder. There is a need to perform tests with an EBR to reproduce actual BUPERS records on this special film because Kodak representatives have indicated that a different film containing a conductive layer may be necessary for high-speed, high-resolution applications. This film is more expensive ($.55 per fiche) and is of very limited availability.

Film for Laser Beam Recorders. The high intensity of the laser beam allows an LBR to write on a variety of high-speed films. LBRs can write on wet-silver, dry-silver, or vesicular films. Vesicular film is the least sensitive and requires a blue writing beam (He-Cd or argon laser). This option was demonstrated by Bell Telephone Laboratories using a Kalvar vesicular film developed to match their particular galvanometer scanner. Reference 3.9 is a report on this system. The film cost and development costs are very low, but the He-Cd laser is not recommended for extended operation because of its relatively low reliability. An operating system using an argon laser to write on vesicular film was not discovered. Vesicular film is currently only used for duplication of microfiche in contact-type printers which use high-intensity illumination.

Dry-silver film is used in existing LBRs, including a 3M LBR COM. Dry-silver film fades when exposed to sunlight for a long period of time. It is not an archival film, but use for duplicates is not an archival application. Dry-silver film will cost less than silver-halide film, since the dry-silver film does not require processing. Therefore, 3M type 7869 dry-silver film is the recommended film for a laser beam recorder.

MITS Film Recommendation. The film recommendations for MITS are summarized in Table 3.7 as a function of the particular recorder selected.

Table 3.7. MITS film recommendations.

Recorder Type	Film Type	Manufacturer	Resolution	Cost Per Fiche: Film ($)	Cost Per Fiche: Develop ($)
CRT COM	Wet-processed silver	Kodak Dacomatic A	160 lines/mm	0.11	0.02
		Kodak Dacomatic E	320 lines/mm	0.11	0.02
		Dupont SR-150	192 lines/mm	0.09	0.02
		Agfa-Gevaert Datarex B	155 lines/mm	0.10	0.02
EBR	Wet-processed silver special fine grain	Kodak SO 438	1500 lines/mm	0.11	0.02
LBR	Vesicular	Kalvar Microlith 1000	350 lines/mm	0.02	0
	Dry-processed silver	3M 7869	300 lines/mm	0.11	0

Since a laser beam recorder is recommended as the MITS output recorder, dry-processed silver-halide film is recommended. Processing will be handled in an automatic heater-developing unit coupled to the output of the recorder.

Image Packing Evaluation

The purpose of this section is to discuss the basic concept of image packed microfiche first introduced in Reference 3.12. In addition, the results of an evaluation of the usefulness of the image packed format as an output format for MITS are presented. A more detailed discussion of the evaluation is presented in Reference 3.13.

Motivation for Image Packing. The standard Navy microfiche personnel record carries images (pages reduced by a factor of 24) arranged on the fiche by document category. Figures 2.1 and 2.2 illustrate the concept. As the figures show, the standard format for the location of these images on microfiche is by allocation of images to rows and by categorizing the rows. A large fraction (perhaps 75 percent) of the film for MPRS microfiche is unoccupied by images. This is to provide space for additions to the records. However, on the proposed MITS facsimile output copy there would be no additions, as the facsimile is of dated value. Therefore, although it is possible to make direct one-to-one copies of the input records, it is preferable to print all of the scanned page images one after the other on the output copies. Thus the film costs will be cut by approximately 75 percent – a significant reduction. Of concern, however, is whether or not the user can efficiently and accurately use this "image packed" format. The results of this evaluation have direct impact on the MITS system design and operating costs.

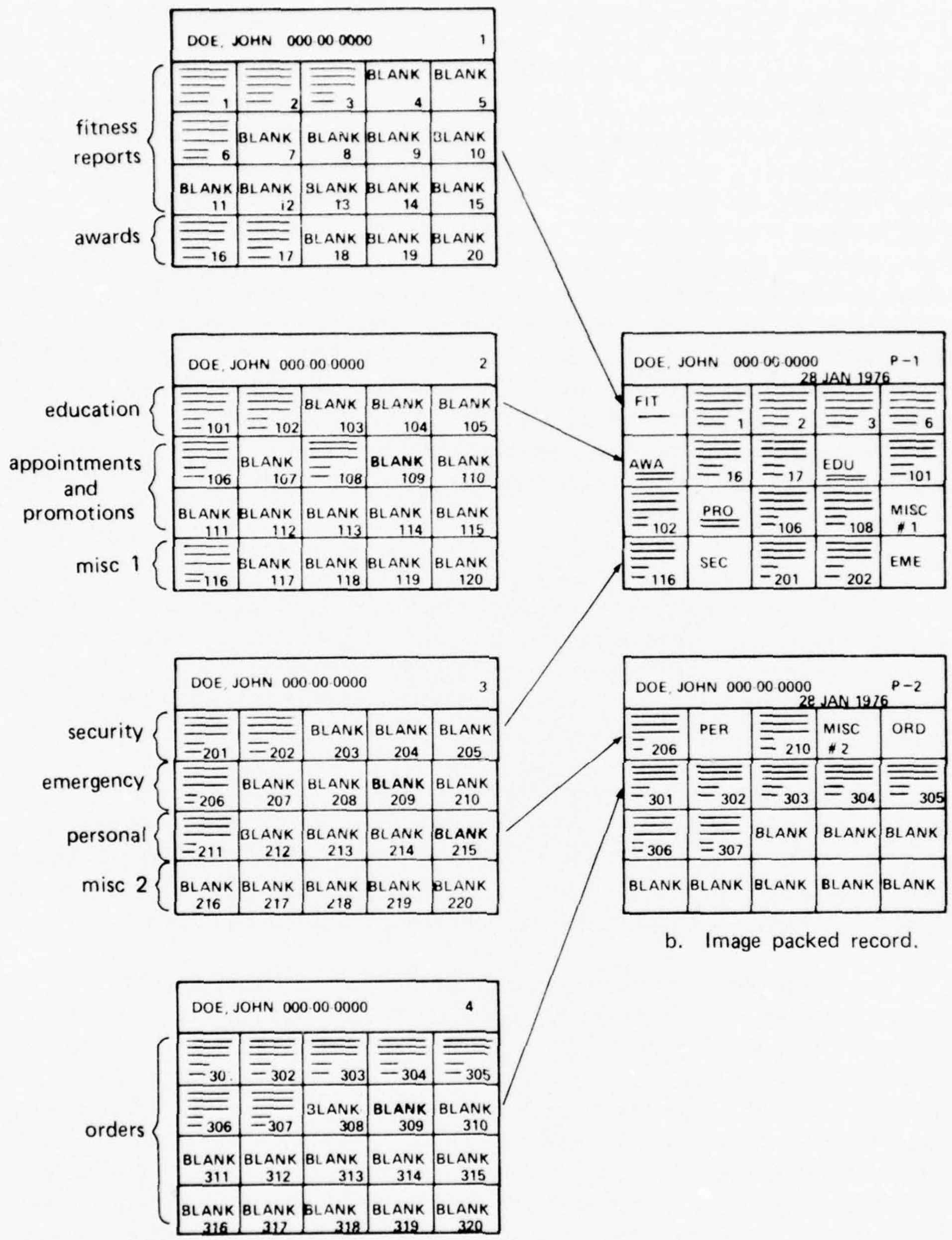
Proposed Image-Packed Format. The recommended packed format is illustrated in Figure 3.15. The packed fiche will contain all of the images from the original record without any of the blank spaces which occur in the original. In addition, category identifier images will be added as noted in the figure to assist in locating the specific documents contained in each category. The inclusion of these eye-readable category identifiers compensates for the fact that the copies are no longer arranged spatially into fields of information (e.g., Educational Data). Images on trailer fiche will be packed in a similar manner on a separate output copy. Thus, a record which contains even a single trailer fiche will result in at least two output fiche, one for the primary images and one for the trailer images.

Approach. The basic approach to evaluating the suggested image-packed format was to have various test subjects recover data from simulated microform personnel records configured in both formats. The quantity actually measured was the time required for data recovery from the standard and packed format microfiche. These times indicate the usage efficiency. In addition, an indication of potential user acceptance of the two formats was obtained with a subjective questionnaire.

Subjects. Twenty-one Naval officers and twenty-six enlisted persons (E-6 and above) volunteered to participate in the study. With the exception of one female enlisted person, all of the subjects were male. The subjects work at various Naval facilities in the San Diego area, including the Naval Training Center (NTC), the Naval Electronics Laboratory Center (NELC), Fleet Combat Direction Systems Training Center Pacific (FCDSTCPAC), and the Anti-Submarine Warfare (ASW) Training Center. The average age of officers and enlisted persons was 33. The average number of years in the Navy for officers and enlisted persons was 12 and 14, respectively. The older, more experienced subjects were used for the test because of their greater familiarity with the contents of Naval personnel records. However, the subjects had little or no previous experience with microfiche copies of personnel records.

Materials. The materials used for the evaluation consisted of a microfiche reader, microfiche copies of simulated Naval personnel records ("standard" and "packed" format copies of an officer's record and of an enlisted person's record), test sheets, and stopwatches.

Two test sheets (one for officers and the other for enlisted persons) were developed to test the perceived ease of operation with the standard and image packed format fiche. Different tests sheets were required for officers and enlisted persons because their personnel



b. Image packed record.

a. Original record.

Figure 3.15. Image packing concept. The number of images per fiche has been reduced for clarity. Normal records can contain up to 98 images per fiche.

records are organized in different formats. Test items were developed which required subjects to recover a variety of facts from the microfiche copies of a sample personnel record. Each questionnaire consisted of ten items to be used for training the test subjects and two sets of five questions to be used for the timed test. Each training item specified the use of either the "standard" or "packed" fiche, alternating every other item for each format to ensure equal exposure to both. The timed test items which specified the use of the packed method and those requiring the use of the standard method were matched for type of data and difficulty of retrieval. There were two forms of each test sheet. Both forms of the officers' test sheet consisted of identical items – only the order in which the packed and standard formats were used to answer the items was altered. Similarly, the two forms of the enlisted men's test sheets were identical in content. In Form 1 of both the officers' and enlisted men's questionnaire, all odd-numbered training items and the first set of timed questions required the use of the "packed" microfiche. All even-numbered training items and the second set of timed questions presented required the use of the "standard" microfiche. The opposite order of presentation was used for Form 2. All test sheets ended with a question regarding personal preference for one of the two formats along with supporting reasons for the stated preference.

Test Design. A simple within-subjects test was used to compare the length of time taken for subjects to recover data using the standard and packed formats. Each subject was timed while recovering five facts using each format. Half of the subjects in each group (i.e., enlisted persons and officers) were timed using the "packed" method first and the "standard" method second. The reverse presentation of formats was used for the other subjects. This counterbalancing was introduced to control for possible effects of order.

A pilot study, using 20 subjects, was run to test the procedures, instructions, and materials. Based on the results of the pilot study, it was decided a priori to reject as extreme any times exceeding 10 minutes. Thus, of the 21 officers and 24 enlisted persons on whom data were taken for the actual study, data from one officer and three enlisted persons was excluded from analysis because they exceeded this time limit.

Procedure. Each subject was told the purpose of the study. Using printed instructions as a guideline, the experimenter described both the "standard" and "packed" formats. The experimenter also demonstrated the use of the microfiche reader. Each subject was then given the ten training questions and instructed to recover the requested facts from the microfiche copies of the specified sample personnel record. During this training period, subjects were encouraged to ask questions and the experimenter helped any subject having difficulty locating certain facts. Once the subjects completed the ten training questions and felt confident that they understood the procedure, the timed part of the test was begun. Using a stopwatch, the experimenter monitored the time it took each subject to answer the first set of five questions. Immediately following completion of the first set, the second set of test items (which required the use of the format not previously used in testing) was administered and timed. Upon completion of the timed part of the test, each subject was asked to answer two subjective questions relating to his perception of the ease of operation with and acceptance of the different formats.

Results. A Fisher t-test was used to test for statistical significance between the group mean times (average time taken to answer the sets of five items). Table 3.8 lists the actual times for each subject. Table 3.9 shows the t-test results. The results of the test

Table 3.8. Times (in minutes) taken to complete each set of five test items.

OFFICERS

Subject Number[1]	Packed	Standard
1	3.98	3.07
2	4.00	3.72
3	4.18	4.70
4	4.20	6.42
5	4.62	3.95
6	4.85	4.88
7	6.32	5.65
8	7.37	5.62
9	7.72	4.27
10	8.52	5.45
	$\overline{X} = 5.57$	$\overline{X} = 4.77$
	SD = 1.74	SD = 1.03
	Standard	**Packed**
11	3.58	3.80
12	5.45	4.35
13	5.45	4.88
14	5.68	3.78
15	5.80	6.60
16	6.45	3.62
17	6.53	3.57
18	6.75	4.97
19	7.17	3.93
20	8.03	4.47
	$\overline{X} = 6.08$	$\overline{X} = 4.39$
	SD = 1.20	SD = .92

$\overline{X}$ = mean

SD = standard deviation

[1]The data for subject 21 was eliminated because his search time exceeded the 10-minute time limit.

Table 3.8. Continued.

ENLISTED PERSONS

Subject Number[1]	Packed	Standard
1	3.02	5.30
2	3.83	3.92
4	4.40	4.92
5	4.83	4.78
6	5.40	3.58
8	5.43	6.52
10	5.63	4.18
11	7.32	4.45
12	7.50	6.35
13	7.65	4.23
	8.45	5.38
	$\overline{X} = 5.77$	$\overline{X} = 4.87$
	SD = 1.66	SD = 4.87
	Standard	**Packed**
14	4.08	2.95
15	4.18	2.87
16	4.38	5.93
17	4.83	5.00
18	5.44	5.25
19	5.95	4.02
20	6.00	4.05
21	6.53	4.32
22	7.92	5.55
23	8.27	6.60
24	8.53	5.95
	$\overline{X} = 6.01$	$\overline{X} = 4.77$
	SD = 1.63	SD = 1.23

$\overline{X}$ = mean

SD = standard deviation

[1] Data for subjects 3, 7, and 9 were eliminated because their search times exceeded the 10-minute time limit.

Table 3.9. Values of "t" for officers and enlisted subjects as a function of fiche format and order of presentation.

	Fisher "t" Value	Probability
Officers		
Standard vs. Packed	.99	NS
Order (first vs. second)	3.46	<.01*
Enlisted		
Standard vs. Packed	.16	NS
Order (first vs. second)	3.45	<.01*

* = significant at .01 level of risk
NS = not significant

show that there was not a statistically significant difference in time between performing operations with the standard and packed formats or the officers or enlisted persons.

Summary and Recommendations. The test results described above indicate that there is not a consistently significant difference between the two formats in time taken for data recovery. Figure 3.16 illustrates the ove ll test results which support this statement. There are advantages and disadvantages to both formats which are subject to personal preference. Additionally, the relative efficiency of data recovery as measured by time may not be an important consideration in choosing one of the two formats for use. The results of the subjective questionnaire used to test personal preference give strong support for the image packed format (34 of 44 preferred the packed format rather than the standard format). Some of the common reasons given for preferring the image-packed method follow: (1) The eye-readable leaders identifying each class of documents make locating information relatively easy. (2) There are fewer fiche to handle which increases convenience in use because there is less need to insert and remove the fiche from the reader when locating desired information. (3) There is no need for reference to a guide for locating documents as there is using the standard method.

It is recommended that BUPERS use the image-packed microfiche format facsimile for copies of Naval microform personnel records rather than the standard microfiche format. This recommendation is based on the following: (1) The image-packed format will make local storage at the remote site more economical by using space more efficiently. (2) This format will require less output film and therefore will cost less than would the standard format. (3) Data recovery using the image-packed format is essentially the same as that using the standard method. (4) Personal preference favors use of the image-packed format.

Output Legibility Criteria

As noted in the resolution determination section, a procedure for measuring and ensuring legibility has been selected. This work is documented in Reference 3.1. This procedure makes use of the IEEE Standard 167A-1975 Facsimile Test Chart. The chart,

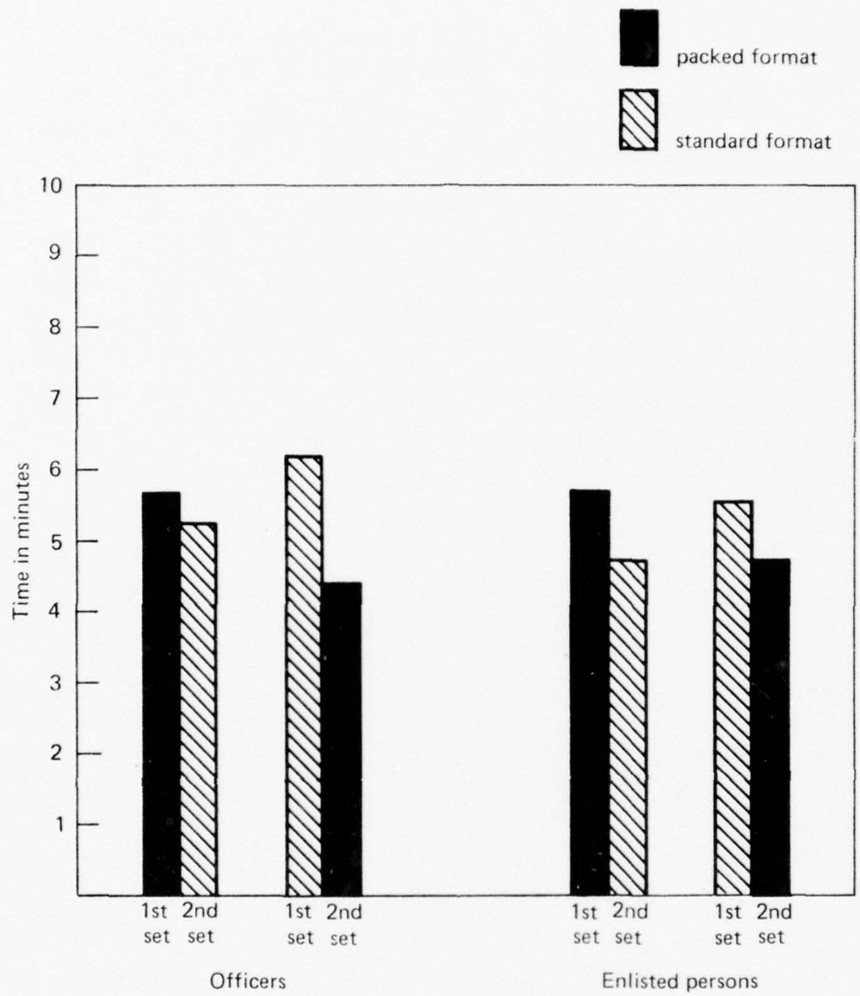


Figure 3.16. Mean times taken to complete sets of five test items using both formats for each group of subjects.

illustrated in Figure 3.17, contains National Bureau of Standards (NBS) bar charts, representative typewritten characters of 4-, 6-, 8-, 10-, and 12-point size, and a sample photograph. This facsimile chart will be microphotographed and mounted on a microfiche.

To perform the system calibration, this test fiche is loaded in the scanner. The fiche is scanned, and the digital output is passed through the compressor over the transmission link to the remote site, where it is input to the decompressor and to the recorder, which recreates a facsimile microfiche. The facsimile is placed in a viewer and the operator inspects for legibility of the lower case, 6-point typewritten characters. In addition, the NBS chart is read to verify 6.3-lines-per-millimeter resolution by detecting separate blank and white bars on the "2.5" section. This test includes Kell factor effects, and legibility of the "2.5" chart is a necessary condition for lower case, 6-point type legibility in context. This test provides a checkout of the entire system and provides two measures of adequate legibility. It is recommended that this test be performed at the beginning and end of each transmission cycle and after any maintenance has been performed.

Figure 3.17. IEEE facsimile test chart (shown reduced).

SUMMARY

In summary, the Options Analysis Phase resulted in the following recommendations:

1. Diazo copies of silver master microfiche can be reliably scanned with laser beam scanners.

2. The recommended scanning resolution is 151 pixels per millimeter (3,840 pixels per inch) and 151 scan lines per millimeter (3,840 lines per inch).

3. The recommended scanner is a laser-beam spinning-mirror scanner. This scanner will scan image-by-image and skip the blank image areas on the input fiche. Fiche input is recommended over a roll film input.

4. The wavelength of the scanning laser has minimal impact on the scanned image signal quality; and, based on cost, availability, and reliability advantages, a helium-neon laser is recommended for scanning the diazo duplicate fiche.

5. A more desirable scanner will be available in the next 1 to 2 years that is based on a charge-coupled-device line-array that will be less expensive and more reliable than the spinning-mirror laser scanner.

6. It is practical to reliably stack and automatically feed diazo duplicate microfiche into a scanner, and a system was found which currently performs this function as well as x-y positions the fiche in front of the scanning beam.

7. The recommended output recorder is a laser-beam spinning mirror recorder. The recorder will actually be identical to the scanner such that each unit could be used for either input or output.

8. The recommended output film with adequate resolution and sensitivity to match the high-speed laser recorder is a dry-processed, silver-halide film. Dry-processed silver film is less expensive than wet silver because there is no cost for processing chemicals.

9. An image-packed format for the output microfiche has been developed and successfully tested with Naval personnel. This format was judged equally acceptable with the standard format; and, because of a 75-percent cost reduction, image packing is recommended.

10. A legibility criteria and calibration procedure has been developed which employs a microfiche of IEEE facsimile chart images to ensure adequate legibility.

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4. MITS FUNCTIONAL DESCRIPTION

The purpose of this section is to provide a general understanding of MITS without providing too many details of component operation. To this end, the major functions (both human and machine) necessary to deliver a requested record to an individual are discussed. They are presented in the order of their occurrence beginning with the individual asking to see his record at a remote site and ending with the viewing of the appropriate facsimile record at the same location.

In order to facilitate implementation of MITS based on the results of the options analysis, a preliminary system design has been prepared. These sections, Section 5 and Section 6 present the details of that design. It is important to point out that the preliminary design has two major objectives. The first is to specify overall system performance and component interactions and identify all critical system parameters as a means of validating the feasibility study results. The second, and perhaps more important, objective of the design is to provide an appropriate set of detailed specifications and a configurational framework on which a final system design can be based. To satisfy these objectives, the operational scenario already presented was expanded and the detailed results are presented below. Sections 5 and 6 cover both the hardware and procedural details necessary to ensure successful implementation of MITS.

THE SYSTEM

Human and Hardware Functional Perspectives

The MITS can be viewed from two primary perspectives. From an electronic or mechanical engineering viewpoint, it can be considered as a collection of very complex electromechanical components that must be made to function properly together. This first perspective dictates that emphasis be placed upon component interfaces with special attention to such factors as data formats, transfer rates, operating speeds, and storage requirements. In line with this viewpoint, the procedural or human functions are important only where they directly impact hardware operation. For example, machine start-up, loading, console operation, and on-line input are all human functions which directly impact hardware operation. This perspective is basic to the material presented in Section 5. The second perspective is one of human factors and emphasizes the procedural aspects of the total system. In the end, it is people who will make MITS work, and this requires that the human/machine interfaces be carefully considered. Factors such as required skill levels, physical layout, and environmental conditions, as well as the distribution of an individual's duties, are important to the success of any system. All of these factors were carefully considered and the results are presented in Section 6. A system flow diagram which combines both the machine and human functions is included as Appendix A.

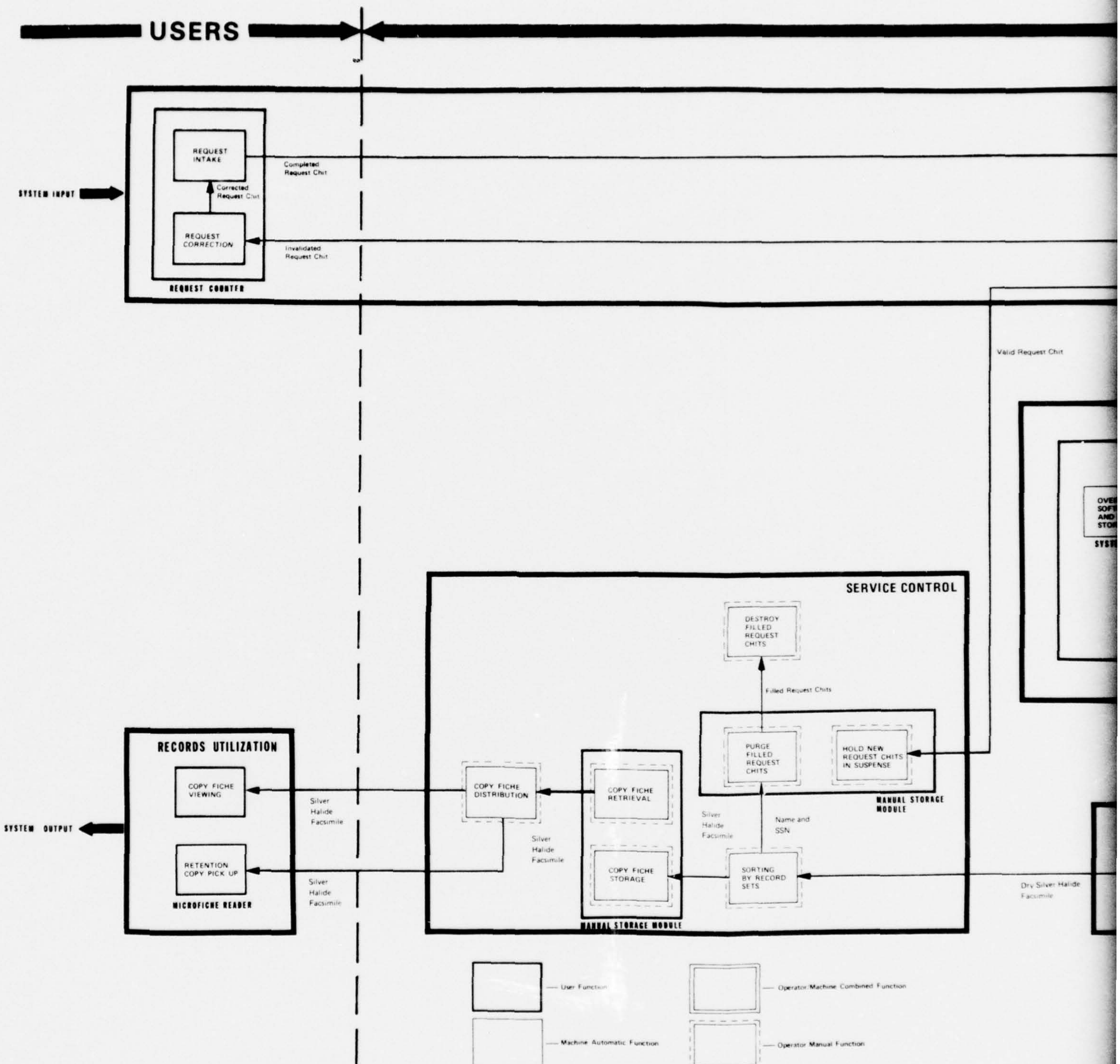
Detailed Functional Description

Figure 4.1 is a functional block diagram of the Microfiche Image Transmission System. Figure 4.1 should be compared to Figure 2.7 to obtain a better understanding of the various functions required for delivery of a facsimile copy to the requester. Both figures have the same basic layout and functional groupings.

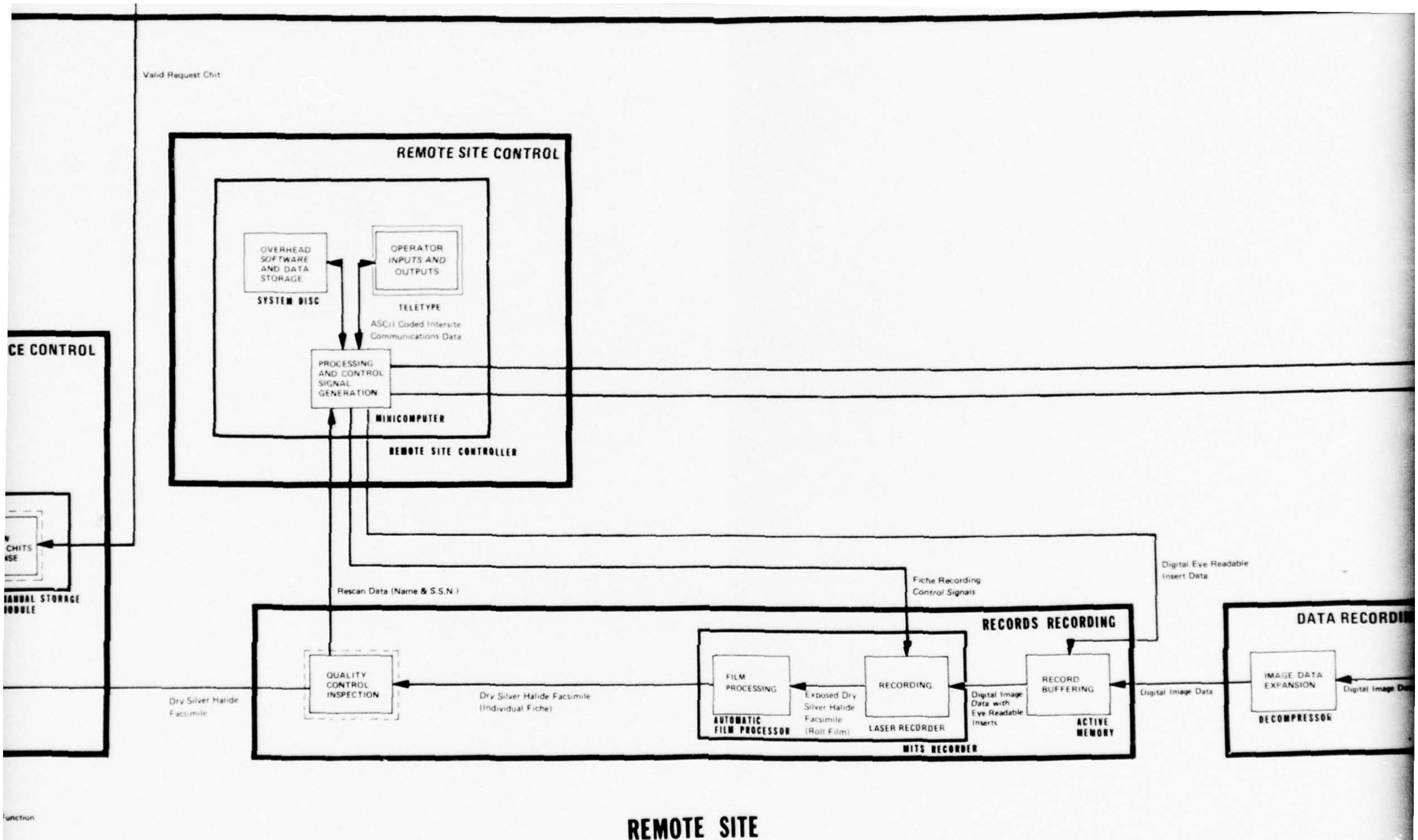
The following sections describe in detail the steps required to accomplish each of the above functions. Again, the reader is referred to Figures 2.7 and 4.1 for a graphic representation of the functions described. All of the descriptions which follow are keyed directly to the figures.

Records Requesting. Records Requesting is a functional area which spans the USER/MITS interface. It also requires procedures at both the remote and central MITS sites. The four major functions which make up this functional area are discussed below. With the exception of the first one, Request Intake, the procedures are primarily automatic and occur instantaneously. Figures 2.7 and 4.1 show this function beginning in the upper left corner.

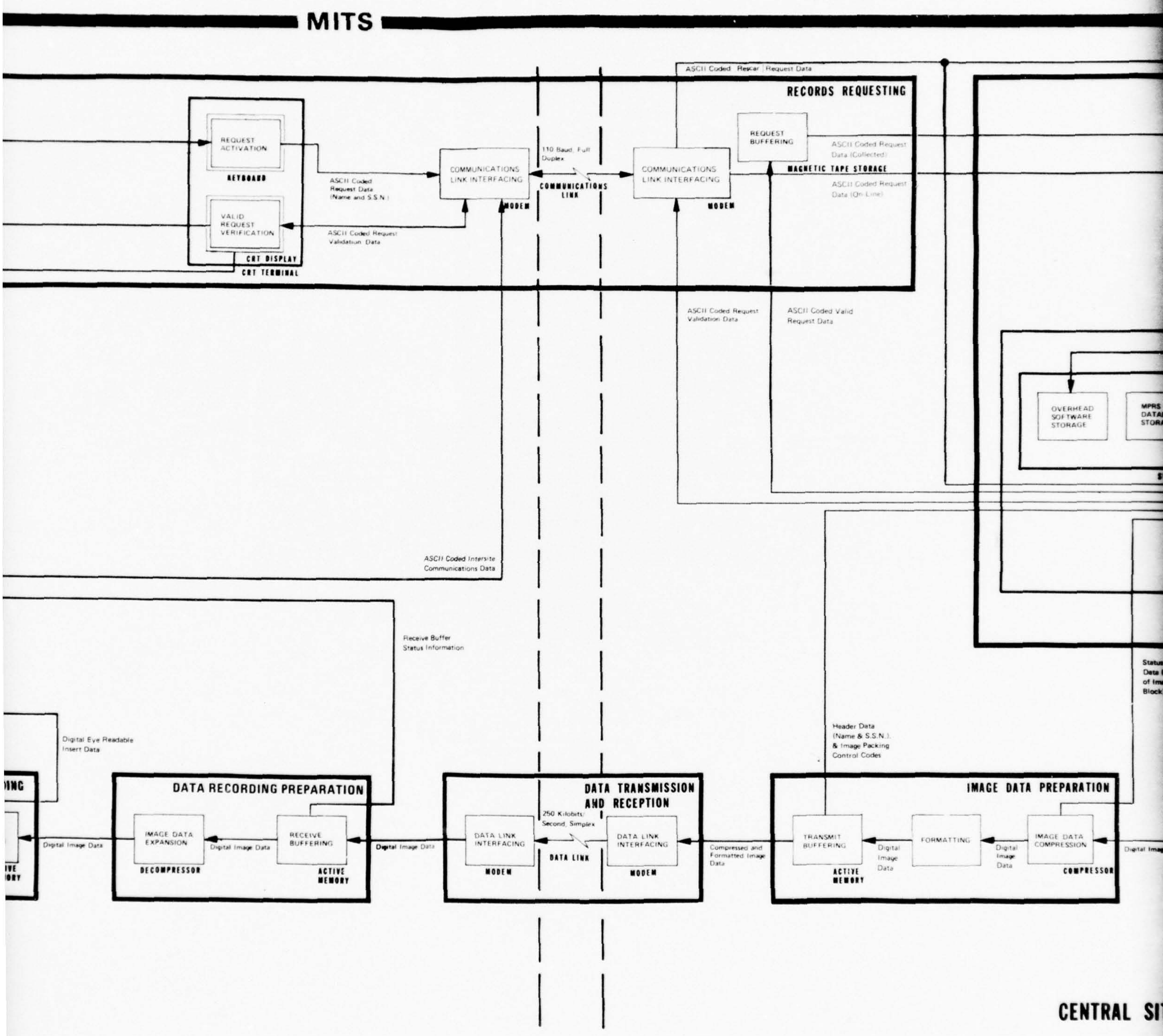
Request Intake. Requests for personnel records via MITS will be placed primarily by individual Naval personnel who wish to see their own records and authorized users within BUPERS. All requests from individual Naval personnel will originate at the remote site (except for personnel stationed in the Washington, D.C., area, who will have no need for MITS). A person at each site will assist the requesters in filling out the request forms. Requests will be received from individuals at the remote site or by telephone. Information from all sources will be entered on request forms or chits and passed on to the request activation function.



USERS
SYSTEM INPUT
REQUEST INTAKE
Corrected Request Chit
REQUEST CORRECTION
REQUEST COUNTER
Completed Request Chit
Invalidated Request Chit
Valid Request Chit
SERVICE CONTROL
DESTROY FILLED REQUEST CHITS
Filled Request Chits
PURGE FILLED REQUEST CHITS
HOLD NEW REQUEST CHITS IN SUSPENSE
MANUAL STORAGE MODULE
RECORDS UTILIZATION
COPY FICHE VIEWING
RETENTION COPY PICK UP
MICROFICHE READER
SYSTEM OUTPUT
Silver Halide Facsimile
COPY FICHE DISTRIBUTION
COPY FICHE RETRIEVAL
COPY FICHE STORAGE
MANUAL STORAGE MODULE
Name and SSN
SORTING BY RECORD SETS
Dry Silver Halide Facsimile
User Function
Machine Automatic Function
Operator/Machine Combined Function
Operator Manual Function


Valid Request Chit
REMOTE SITE CONTROL
OVERHEAD SOFTWARE AND DATA STORAGE
SYSTEM DISC
OPERATOR INPUTS AND OUTPUTS
TELETYPE
ASCII Coded Intersite Communications Data
PROCESSING AND CONTROL SIGNAL GENERATION
MINICOMPUTER
REMOTE SITE CONTROLLER
CE CONTROL
CHITS
MANUAL STORAGE
MODULE
Rescan Data (Name & S.S.N.)
Fiche Recording Control Signals
Digital Eye Readable Insert Data
RECORDS RECORDING
QUALITY CONTROL INSPECTION
Dry Silver Halide Facsimile
Dry Silver Halide Facsimile (Individual Fiche)
FILM PROCESSING
AUTOMATIC FILM PROCESSOR
Exposed Dry Silver Halide Facsimile (Roll Film)
RECORDING
LASER RECORDER
Digital Image Data with Eye Readable Inserts
RECORD BUFFERING
ACTIVE MEMORY
MITS RECORDER
Digital Image Data
DATA RECORDI
IMAGE DATA EXPANSION
DECOMPRESSOR
Function
REMOTE SITE

73


MITS
ASCII Coded Rescan Request Data
RECORDS REQUESTING
REQUEST ACTIVATION
KEYBOARD
ASCII Coded Request Data (Name and S.S.N.)
COMMUNICATIONS LINK INTERFACING
MODEM
110 Baud, Full Duplex
COMMUNICATIONS LINK
REQUEST BUFFERING
ASCII Coded Request Data (Collected)
MAGNETIC TAPE STORAGE
ASCII Coded Request Data (On-Line)
VALID REQUEST VERIFICATION
ASCII Coded Request Validation Data
CRT DISPLAY
CRT TERMINAL
ASCII Coded Request Validation Data
ASCII Coded Valid Request Data
OVERHEAD SOFTWARE STORAGE
ASCII Coded Intersite Communications Data
Receive Buffer Status Information
Digital Eye Readable Insert Data
Header Data (Name & S.S.N.), & Image Packing Control Codes
DATA RECORDING PREPARATION
IMAGE DATA EXPANSION
DECOMPRESSOR
RECEIVE BUFFERING
ACTIVE MEMORY
Digital Image Data
DATA TRANSMISSION AND RECEPTION
DATA LINK INTERFACING
250 Kilobits/Second, Simplex
DATA LINK
Compressed and Formatted Image Data
IMAGE DATA PREPARATION
TRANSMIT BUFFERING
FORMATTING
IMAGE DATA COMPRESSION
COMPRESSOR
Digital Image Data
CENTRAL SIT

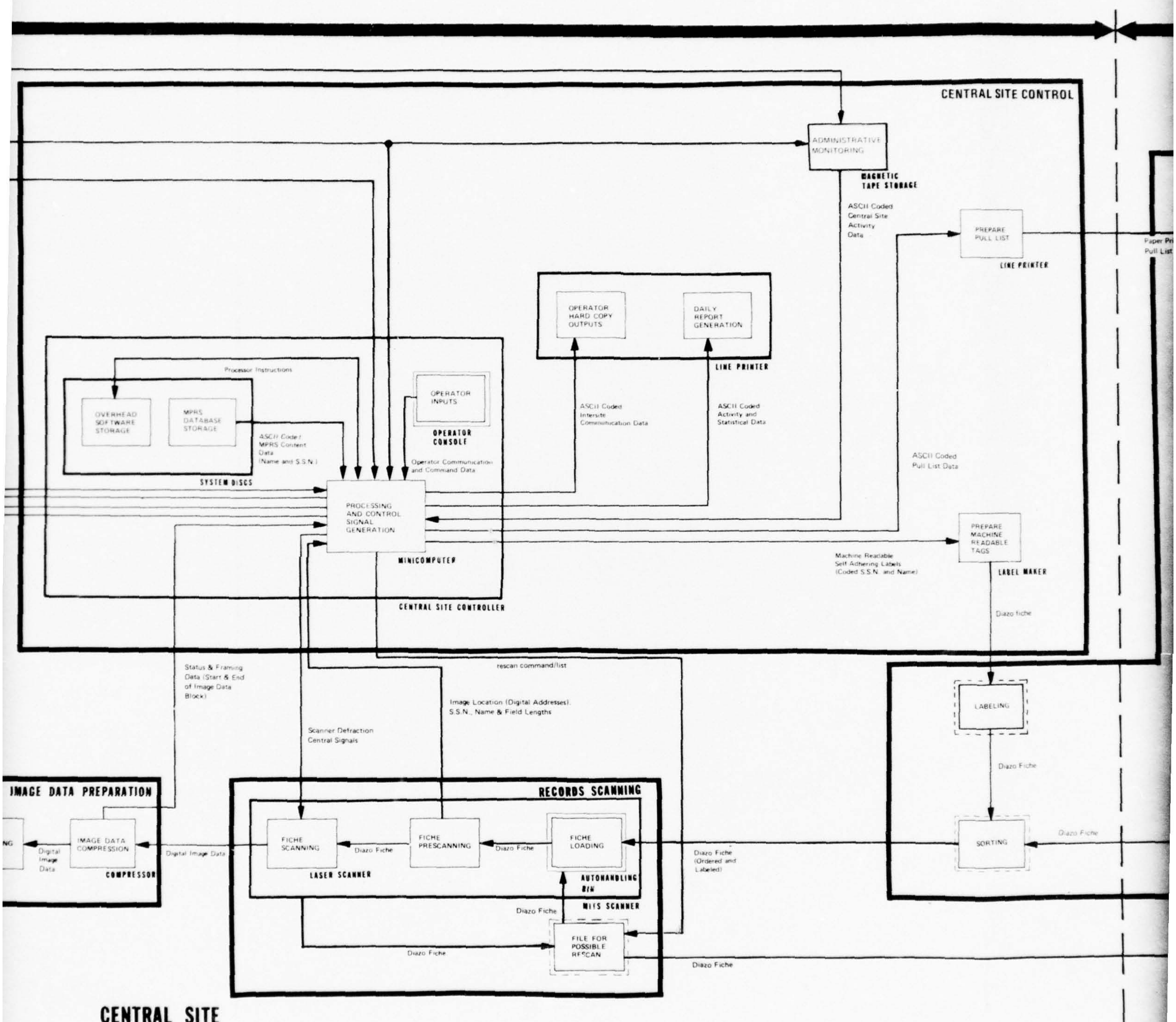


Figure 4.1. MITS functional b

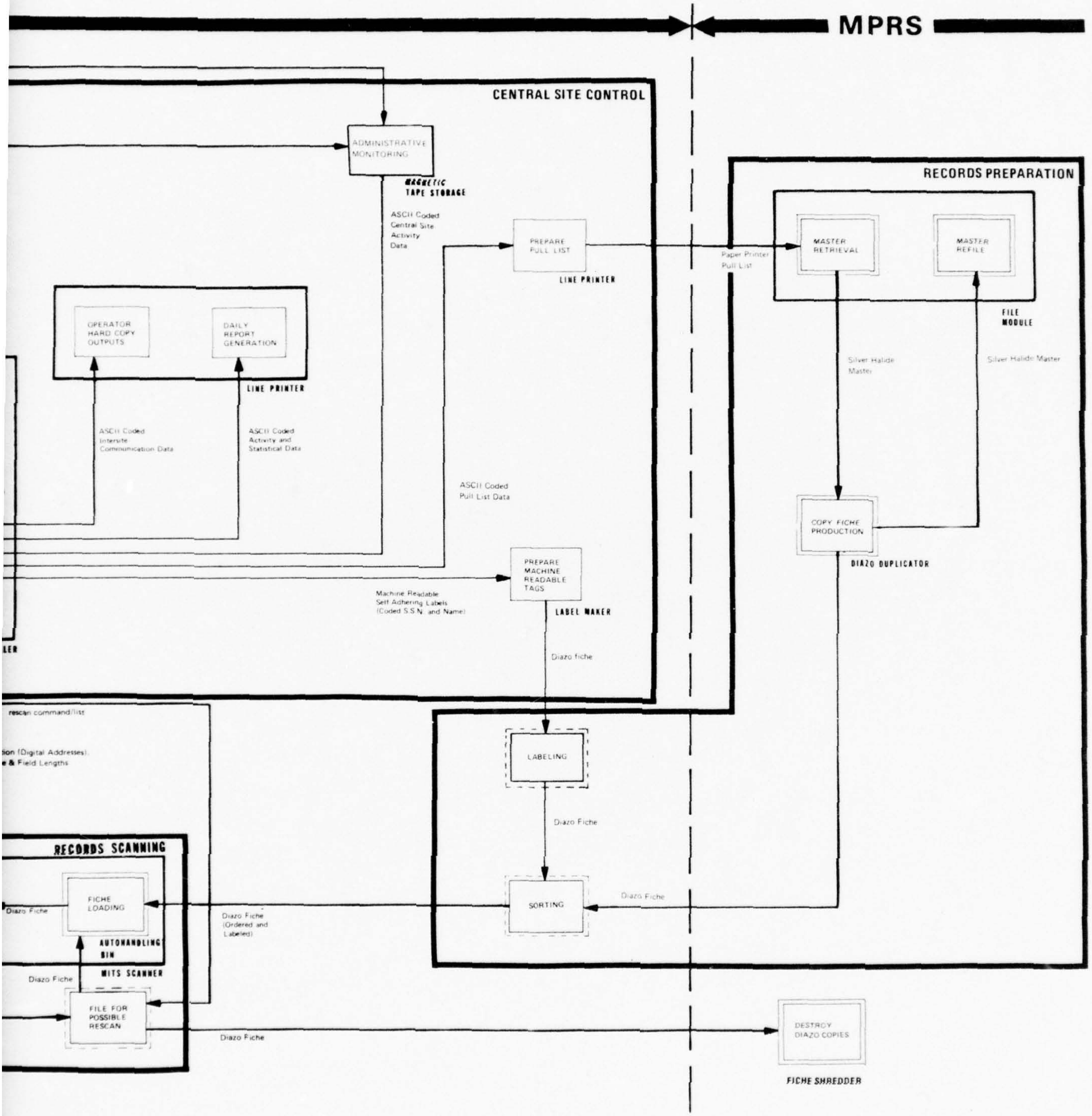


Figure 4.1. MITS functional block diagram.

5

Request Activation. Request activation entails an operator keystroking the request information via an on-line terminal to the central site in Washington, D.C. The request data will include the individual's name and SSN.

Request Validation. Request validation is primarily an automated function which commences with reception of the request information at the central site. This is followed by the computerized matching of SSNs to the BUPERS data base to ensure the existence of the record in the MPRS converted microfiche file. Results of this comparison are communicated to the remote site as either a valid request or an invalid request. Notification of an invalid request will result in retransmission of the request data from the remote site with updated or corrected request information. Once a request has been validated, a copy of the request chit is given to the user and one is filed in the pending request file. This process is illustrated in Figure 4.1.

Request Buffering. At the central site, all requests received during a specific interval of time are recorded in the request buffer. At the end of this time, or if requests exceed a predetermined number before the time interval has elapsed, the system controller, located at the central site, is activated to transfer the buffer for control processing. Upon completion of the transfer the buffer becomes available for receipt of additional requests.

It should be noted that the request data are transmitted to Washington, D.C., via a data communication channel. The bandwidth required for this data is extremely small, and, therefore, the request link would be the same as that for the scan data transmitted back to the remote site.

Central Site Control. The central site controller merits special attention. As its placement in Figure 2.7 indicates, the central site controller is the "center" of all automatic functions which take place at the central site. Therefore, it is a component of each of these functions.

Controller. The central site controller will provide a data storage capability and overall coordination of operations at the central site. The primary system controller functions include the following:

1. Sorting of the request data by storage module and destination.
2. Generation of a records pull list.
3. Coordination of the scanners, data compressors, and buffers.
4. Miscellaneous system control and synchronization.

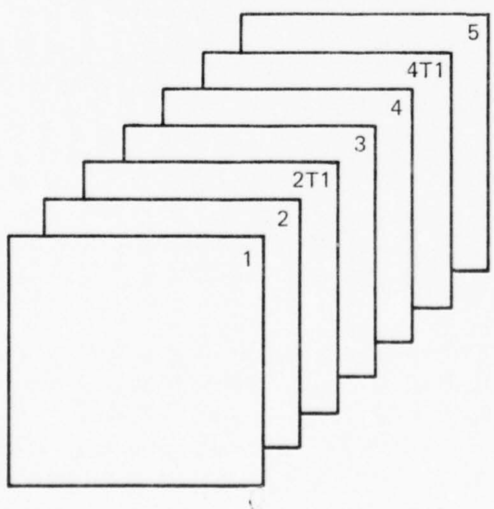
Administrative Monitoring and Report Generation. In addition to its normal control functions, the central site controller periodically (i.e., once per shift or once per day) accomplishes an administrative report production. As Figure 4.1 shows, the request and other site activity information are used to produce this report. Although not directly related to delivering record information to the requester, this report is important for audit trail and production control purposes.

Records Preparation. This is another of the major areas which involve more than MITS procedures. Two of the Records Preparation component procedures are existing MPRS procedures. However, they are included here to illustrate exactly what actions are required to deliver a diazo duplicate record to the MITS scanner for processing.

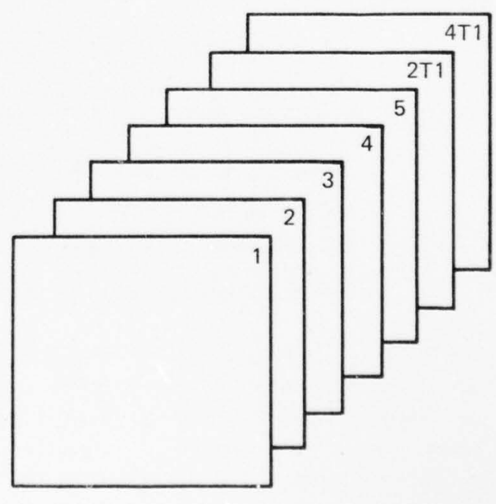
Storage and Retrieval. The storage and retrieval of master records will be accomplished by BUPERS contractor personnel in the same manner as it is now performed. This semiautomatic storage and retrieval system is well described in Reference 4.1. Storage and retrieval entails pulling of the master fiche according to a pull list generated by the controller, delivering them to a duplication area, and refiling the masters in the permanent storage file after duplication is completed. The proper destination of facsimile records will be ensured by retrieving according to a separate pull list for each remote site.

Duplication of Masters. Diazo copies are made of the masters to minimize the time that masters are out of the file and to avoid damage to them during automatic handling in the scanner. The duplication function is twofold. The silver-halide microfiche masters are manually fed to a duplicator, and diazo duplicates suitable for scanning are produced. This small amount of manual handling minimizes potential damage to the masters.

Ordering and Labeling. After duplication, the diazo copies of the master which correspond to an individual's record will be ordered such that all primary fiche are in numerical order followed by all trailer fiche (see Figure 4.2). As discussed in the Options Analysis section of this report, a trailer fiche is a microfiche carrier which is made necessary when all of the fields on the primary carrier are filled. Additional images are placed in the same field located on the trailer fiche, which immediately follows the primary fiche that contains the filled field. Trailer fiche are numbered the same as the primary fiche they follow but include the letter T. As Figure 4.2 indicates, the diazo copy is reordered but order of the master record itself is preserved. The purpose of the reordering is to facilitate image packing at the remote site.



a. Sequence of master record



b. Sequence of diazo copies for MITS

Figure 4.2. Fiche ordering for scanning.

After sorting, a machine-readable code will be automatically attached to the diazo duplicate on the existing header area (see Figures 2.1 and 2.2). This code denotes the individual's social security number and was produced by the controller in parallel with the pull lists. This coded SSN will be used to maintain record integrity as well as an audit trail during scanning.

Records Scanning. The scanning operation commences when the stack of individual fiche is placed in an automatic loading bin. The scanner then optically scans the individual microimages at a specified resolution and outputs a representative serial digital data stream with an image represented by 2.9 million binary bits. Blank images will be detected and skipped by the scanner under direction of the scanner controller. Images are scanned in this manner, one at a time, until the entire fiche is completed. After being scanned the fiche will move to an output collection point. They will be held in suspense (for possible rescanning) until verification of receipt at the remote site, then destroyed in accordance with BUPERS procedures.

Image Data Preparation. The three procedures which make up this functional area are necessary to provide the satellite link with formatted and compressed image data at a rate which takes full advantage of the available transmission bandwidth.

Image Data Compression*. Data from the scanner is received by the compressor at the same speed that it is output by the scanner. The data is then encoded to reduce repetitive information. This results in a net reduction of the amount of data representing the source images. The data output of the microfiche scanner is approximately 2.9 million binary bits per microimage. It is possible to transmit all of the image data to the remote site, but this would be needlessly expensive, since transmission link costs are based upon the amount of data transmitted. However, the data can be compressed, taking advantage of the fact that most of the area of the images is black background with white letters and writing. It is easily within the state-of-the-art to achieve a data compression ratio of 5:1 with negligible loss of image quality. Thus, by transmitting only one-fifth of the quantity of data, or approximately 580 thousand bits per image, the link cost can be reduced significantly.

Data Formatting. After compression and before transmission, it is necessary to augment the image data. The controller will insert digital control words which will be used by the MITS recorder at the remote site.

Transmit Buffering. The transmit buffer receives the compressed data and stores a selected number of images in a temporary memory. At the same time, these image data are passed on to the central site modem and then to the transmission link. At the remote site the receiving controller will detect errors and acknowledge a successful transmission via a coded signal to the transmit buffer. The data held in suspense in the buffer will then be purged image by image so that the newest scanned image data pushes the oldest image data from the buffer. If an error is detected, the return signal will initiate a retransmission of the image from the buffer memory. Rescanning of the images is not required.

**BUPERS has specified that the content of personnel records within MITS be handled with consideration for their confidentiality even though they are not officially classified. The data compression itself will suffice to maintain an adequate level of confidentiality of the personnel records. Accidental dissemination of record content is not possible.*

Data Transmission and Reception. The remote and central MITS sites must be tied together with a high-bandwidth data and communications link. The most reasonable method for its implementation is a satellite link. This is true because of the large volume of data that must be transmitted over great distances. The three component procedures of this major functional area are outlined below.

Link Interfacing. Interface devices are required at each end of the transmission links. These self-contained units are provided by the data link leasing company to match incoming data voltage levels, frequencies, and data rates to the transmission link. The interface device itself is referred to as a modem (from modulator-demodulator).

Satellite Transmission. Data transmission via satellite is feasible between most metropolitan areas in the United States. An earth station at each end of a satellite link provides the antennas, transmitter, receiver, and appropriate control circuitry. This facility is also leased from the satellite company. Satellite bandwidth is available up to 37 mHz with virtually any intermediate bandwidth available at a proportional monthly cost.

Terrestrial Transmission. The central MITS site and most potential remote sites are not located near existing earth stations. To justify the recurring cost and installation cost of an earth station at the MITS site, two additional non-MITS users are needed to share the station and the cost.

If this is not practical, a terrestrial communication channel will be required between each site and the nearest existing earth station. An example is an earth station in Los Angeles communicating with San Diego via terrestrial line. Most terrestrial lines are provided by telephone companies to the satellite company. Interfaces between MITS equipment and the terrestrial lines are required in addition to the modems required to interface with the satellite. The terrestrial lines are only required if cost sharing of a dedicated earth station is not practical.

Remote Site Control. The remote site controller has functions analogous to its counterpart at the central site. It provides for the overall coordination of remote site operations. Specific functions include these:

1. Status monitoring of all automatic processes.
2. Error detection at the receive buffer.
3. Creation of recorder control commands from transmitted control words.
4. Insertion of eye-readable images.
5. Data storage.
6. Coordination, sequencing, and synchronization of all remote site hardware.

Data Recording Preparation. At the remote site it will first be necessary to receive the transmitted image data and recording control word information. In addition, the compressed image data must be expanded to the original bandwidth.

Receive Buffering. The receive buffer will perform temporary data storage, error detection, and mass storage, and will interface with the output recorder. The buffer will receive data from the link and hold groups of images for error detection. An error message will result in retransmission of the data.

Data Expansion. Serial data from the buffer is received by the decompressor at the transmission rate. The data is then expanded to reproduce the original 2.9 million bits image representation at the original resolution. After expansion and under the control of the remote site controller, locally stored eye-readable identifier images will be inserted into the data stream. These are made necessary because the original imagery has been rearranged to conserve output film costs. The identifier images specify the information categories which are implied by the location of the document image in the standard or original format (see Figures 2.1 and 2.2).

Records Recording. The major goal of MITS is to provide the requester with an accurate copy of his personnel record. This functional area is one of the most important in accomplishing that goal. It produces a dry silver halide facsimile record which is ready for use by the requester.

Recording. The laser recorder will convert the incoming digital data to a reconstructed film image in a microfiche format at the original 24X reduction. An unexposed roll of dry silver film will be loaded into the recorder. Directed by the recorder controller, the scanned image is then reproduced on the film. The fiche will be exposed image by image. No blank images will precede the last filled image area.

Processing. Film processing and cutting into fiche will be provided at the output of the recorder. It is anticipated that this processing will be automatic and an integral part of the MITS recording device.

Quality Control. After processing, the batch of microfiche records must be spot-checked to ensure that the images were properly exposed and developed. This is accomplished manually with the aid of a standard microfiche viewer and a photographic background densitometer. The detection of an improperly exposed or processed batch of records will result in the retransmission of the entire batch from the central site.

Service Control. This functional area comprises all the procedures which are necessary to prepare the facsimile record for eventual delivery to the requester. All administrative functions which are required at the remote site (i.e., request logging, audit trail tracking, and receipting) are also part of this area.

Records Sorting. The output facsimile records are sorted into individual files. An individual's record may contain one or more fiche with the average about two. This is in contrast to the three to six fiche which made up the original record. Both the original and facsimile records contain the same number of record images, however, the output copy is rearranged to conserve film.

Pending Request Update. The request chit is removed from the pending request file. This allows remote site service control personnel to keep accurate track of outstanding requests.

Copy Fiche Storage and Retrieval. The output copy fiche at each site are ordered by SSN and loaded into a temporary holding file. When the requester arrives to receive requested records, the particular fiche will be retrieved from the file and presented

to the individual. The temporary file will have a capacity for one month's volume and is ordered by week of receipt of the facsimile record.

Copy Fiche Distribution. The fiche are distributed to the requesters when they appear in person at the recording site. All individuals will be required to sign the receipt log before obtaining their facsimile record. Fiche will become the property of the requester. Should the individual choose to leave the copy at the remote site, it will be destroyed in a manner similar to the diazo copy made at the central site.

Records Utilization. The final interface between MITS and the user is Records Utilization. The requester can view the facsimile record at the remote site; an appropriate number of microfiche viewers are provided for this purpose.

Copy Fiche Viewing. A limited number of microfiche viewers and instructions for their use will be provided at the recording site. Hard copy (e.g., paper) facilities are not planned for remote sites.

REFERENCE

4.1 PRC Information Sciences Company. Bureau of Naval Personnel (BUPERS) Microform Personnel Records System, Implementation Plan. PRC, McLean, VA: Volume III. System Maintenance and Utilization, Revised November 1974.

5. SYSTEM DESIGN: HARDWARE

The hardware portion of the preliminary design, which is presented in this section, is directed at the investigation of control and interfacing requirements that exist when the individual devices selected in the options analysis are integrated into a system. A more detailed presentation of the preliminary hardware system design is documented in Reference 5.1.

Figure 5.1 reveals a basic structure that corresponds to the MITS functional diagrams given earlier (Figures 2.7 and 4.1). However, in this figure, emphasis is on the remote and central site controllers. This emphasis is meaningful since all of the other equipment illustrated is coordinated by and interfaced with these controllers. Operations that are external to the controlled hardware or which involve manual or stand-alone sequences are not included in the figure or in this discussion. The signal flow paths show that the various components communicate with each other under command from the respective controllers. The components also provide necessary status information to the controllers.

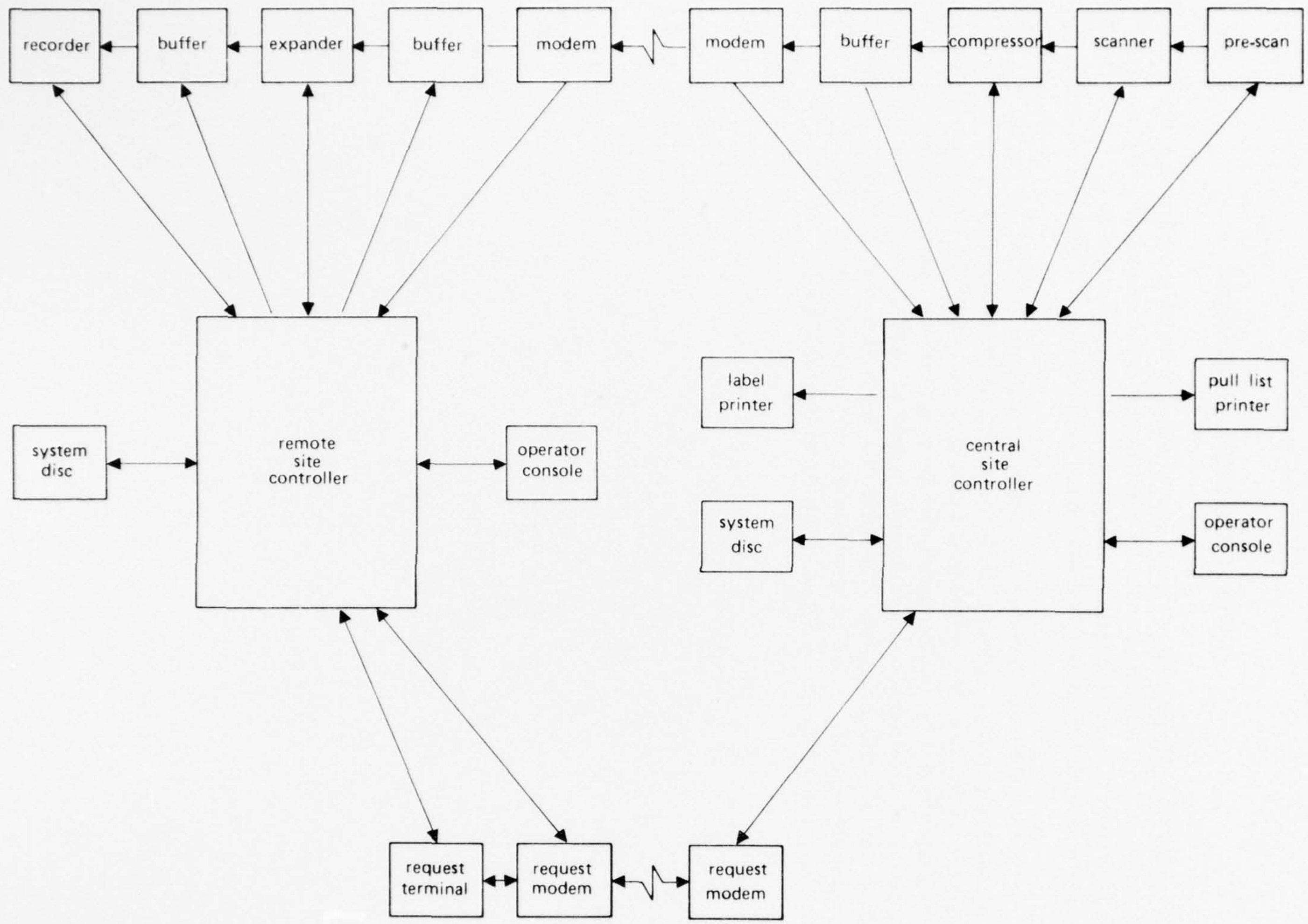


Figure 5.1. Major system components which interface with controllers.

DESIGN CONSIDERATIONS

Specific system design elements considered in developing the controller and interface requirements include the following:

1. The availability of standard devices from a number of vendors having performance ranges which satisfy the MITS requirements

2. The maximum, minimum, and average data rates and the data format compatibility

3. The distribution of control functions between the individual devices and the central controller

4. The access to status information needed for control sequencing at the appropriate time in a usable form

5. The latency of responses to control directives

6. The storage requirements for control and interim data.

Detailed component selections to the manufacturer and model number level were not made a part of this preliminary design. By the use of the options analysis results, generic types have been selected so that the critical parameters could be established. The control, timing, and sequencing requirements have also been examined to produce a preliminary specification for the controllers required at the central and remote sites. Finally, the signal flow through the system and each component interface have been evaluated from a task functional approach to verify system performance.

COMPONENTS

As a result of the options analysis, many of the characteristics of the individual components were determined. Those parameters that have a direct effect upon the system design are presented in Table 5.1, and the interfacing requirements are listed in Table 5.2. Items that are typically purchased as a subsystem or with a standard interface are not detailed in Table 5.2. The following sections will describe in specific detail how the individual elements in these tables influence system performance.

Table 5.1. System design components.

Component	Critical Features
Request Terminal	Standard Device; serial interface; interactive CRT
Communication Link	Standard Modems; voice grade link; full duplex
Request Buffer	Controller memory resident; verification function
Duplicator	Manual operation; no controller interface
Pull List Printer	Standard alphanumeric printer
Scanner	Image scan; feed and index control
Data Compressor	5:1 compression; demand clocked
Transmit Buffer	Solid state memory; independent asynchronous ports; external clocking
Data Link	Serial modems; self clocking; uniform rate
Receive Buffer	Solid state memory; asynchronous ports; external clocking
Data Expander	Four image fields; recorder format; extracts I.D. and control
Recorder Buffer	One-image field; demand clocked
Recorder	Image oriented; feed and index control; automatic film process

Table 5.2. Critical system interfaces.

Component	Inputs			Outputs			Controller Signals	
	Signal	Source	Rate	Signal	Destination	Rate	To	From
Prescanner	Fiche	Input Feed Mechanism	One every: 60 sec aver; 1.0 sec min 100 sec max	Fiche	Scanner	Same as Input	Blank Locations Identification Data	
Scanner	Fiche	Prescanner	Same as Prescanner	Digitized Image	Compressor	7.5×10^6 bps max; 3×10^6 bits per image per 2.4 sec average		Feed Image Index Start Scan
Compressor	Digitized Image	Scanner	See Scanner Output	Compressed Digital Image	Buffer Storage	250K bps aver; 3×10^6 bps max	End of Image	
Scan Buffer	Compressed Digital Image	Compressor	250K bps aver; 3×10^6 bps max	Formatted Data Stream	Satellite Link Modem	250K bps uniform	Current Input and Output Address	Identification Data Recorder Controls
Receiver Buffer	Formatted Data Stream	Satellite Link Modem	250K bps uniform	Formatted Data Stream	Expander	250K bps aver; 3×10^6 bps max	Identification recorder controls end of image I/O addresses	
Expander	Compressed Digital Image	Receiver Buffer	250K bps aver; 3×10^6 bps max	Recorder Image Data	Record buffer	3×10^6 bps	End of Image	Start Expansion
Record Buffer	Recorder Image Data	Expander	3×10^6 bps	Recorder Image Data	Recorder	7.5×10^6 bps max; 3×10^6 bits per image per 2.4 sec average		
Recorder	Recorder Image Data	Record Buffer	7.5×10^6 bps max; 3×10^6 bits per image per 2.4 sec average	Fiche	Distribution	One every 120 sec average	End of Record	Feed Image index Start record Identification

CRITICAL SYSTEM INTERFACES

This section describes the various system hardware interfaces required for the operation of MITS. Although several of the functional headings are identical to those in the preceding detailed functional description, only those which are accomplished entirely or in part by hardware are described here. The description emphasis is on data and control signal flow between components which must be integrated into a smooth system operation. The system controllers, which monitor and coordinate the desired signal flow, are described in the subsequent two sections.

The individual interfaces will be examined with respect to the flow of data and control information within the system. Each functional entity has its own requirements for information necessary to its timely operation, and, in turn, it provides an account of its individual status to the system. The immediate concern is with the data flow along the processing stream from the receipt of requests to the delivery of duplicate fiche at the remote locations. Communications with the central controller are included where essential to the description of this data flow. This section is necessarily very detailed and much technical terminology is used. The reader is referred to Appendix C for a complete explanation of these terms.

Records Requesting

System operation is initiated when an operator enters a request on the keyboard of the request terminal. The identification information consists of the name and SSN. This information will consist of approximately thirty characters input to the terminal at a maximum rate of 10 characters per second. In response to this message, the central site controller will return a response of approximately the same length consisting of a retransmission of the request data as a verification that such a file identification is valid. If a search of the central site MPRS data base does not verify the request, a message indicating this fact will be received (e.g., SSN 123-45-6789 NOT FOUND).

A full two-way asynchronous communication link operating at 110 baud is required between the remote site and the central location to support the records requesting function during that portion of the day when a remote site is accepting requests. The modem required at the remote site would be an integral part of the terminal and provide the conversion from the digital information formats used by the keyboard/printer to the serial analog formats of the communication link. At the central site, a compatible modem would be available as a peripheral device to the controller, converting data from the communication channel analog format to a digital form for the controller. The received requests, after verification, are stored in the active memory of the controller.

Records Preparation

At regular intervals, the central controller produces a printed pull list used for the extraction of the requested master files from storage. Two other items are also generated: a printed audit list used at the duplication station for verification of the entry of fiche into the scan and transmission process, and printed identification labels containing machine-readable encoded SSNs to be attached to the duplicate fiche before scanning.

The steps of pulling master records, duplication, returning masters, ordering and labeling duplicates, and preparing scanner input blocks are essentially asynchronous manual operations. No communication is required with the controller or other automatic devices. These operations are initiated by the pull lists and result in production of the scanner-ready duplicates and any audit information related to inaccessible master files. Audit information is entered on the central controller console for transmission to the remote site.

Records Scanning

At the specified average rate of 300 requests per day, the scanner must process an estimated 1,200 individual fiche in a 20-hour period. This requires an average of 1 minute per fiche, or 2.4 seconds per individual page image. This time includes all handling time. The first stage of data extraction from the duplicate fiche is a prescan station that reads the machine-readable label on each fiche and passes this information to the controller over a digital interface. In addition to the identification, the prescan also examines each of the 98 image locations on the fiche and determines all filled fields. These data are stored in the scanner control logic for use in determining the image sequence. These are also sent to the central controller to be used for the insertion of eye-readable category designators and the image packing of output fiche.

After the prescan stage, fiche are fed to the scanner for conversion into a serial binary data stream. Upon completion of the scan of a fiche, the next fiche in the input is moved into position with its first occupied image field in the scan position. Scanning is initiated by a command from the central controller, and the page image field is scanned with a format as shown in Figure 5.2. The scanner data stream is 2.9×10^6 bits in 500 milliseconds with an active scan ratio of 80 percent, which yields an average data rate of 7.5×10^6 per second into the data compressor. At the end of the 500-millisecond scan time, the fiche is moved to the next image field according to the stored information from the prescan, and the scanner waits for the next command from the controller. In addition to the raw data stream, the scanner provides over its interface a synchronous clock signal, start- and end-of-scan-line signals, and an end-of-image-field signal. These signals are used by the data compressor for timing information and to format the data.

Data Preparation

The data compressor has only a minimal amount of internal storage as required for its compression algorithm. Data flow through the device must track the input and be able to process it at the 7.5×10^6 bits per second rate. Data flow through the compressor is illustrated in Figure 5.3. Output from the compressor will consist of the data stream at an average of 20 percent of the input volume (5:1 compression), but the data rate may equal the input rate at its maximum. Line and frame information from the scanner will be incorporated into the data stream by the compression algorithm. An output clock will be provided for use by the scanner buffer. It will be asynchronous and nonuniform as dictated by the statistical variation in the instantaneous compression ratio. Both the buffer and the central controller should also be supplied with an end-of-image-field signal.

The scan buffer has the storage capacity to store four compressed image fields reduced to 20 percent of their raw data size. These 2.4×10^6 bits of random-access memory have

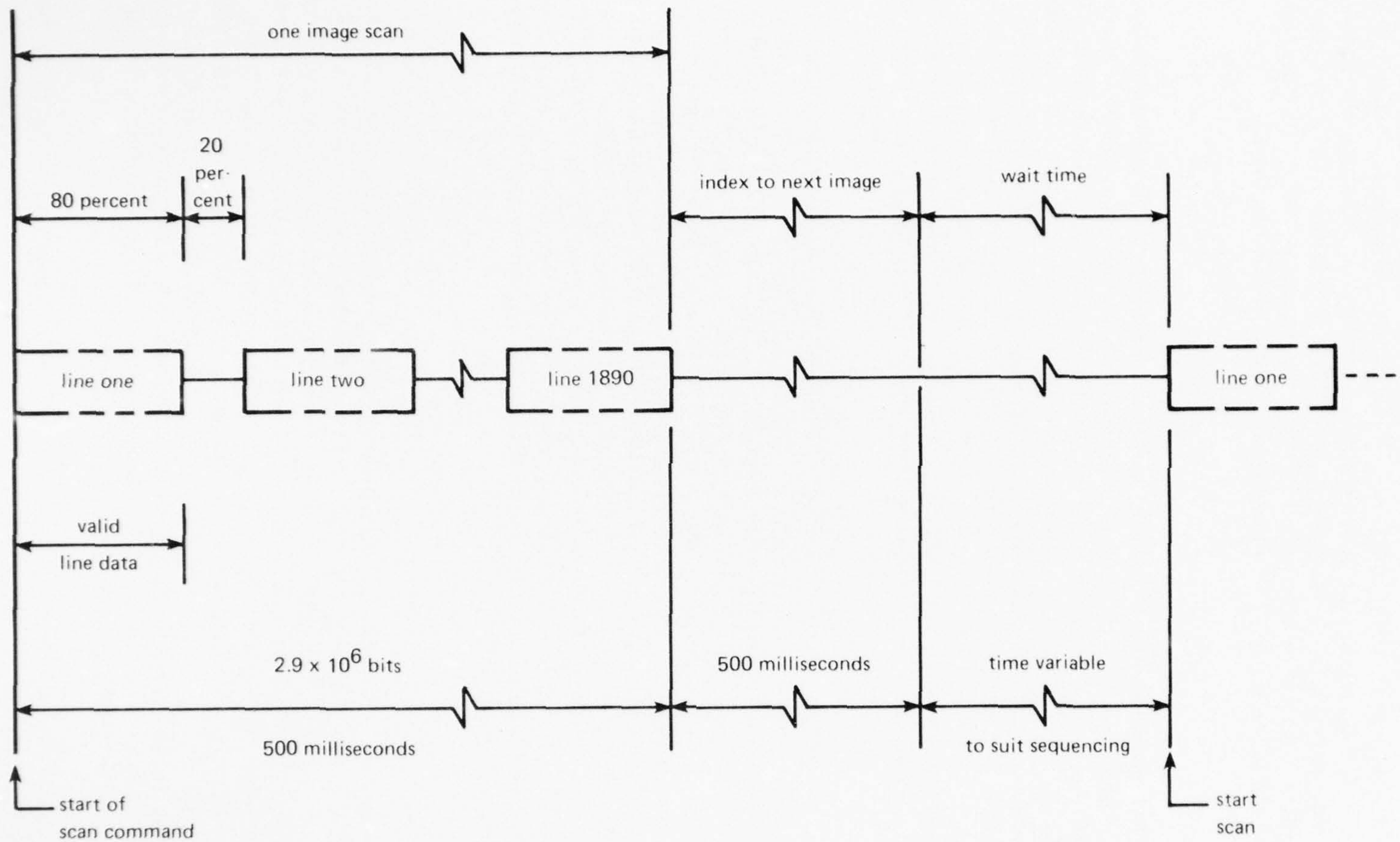


Figure 5.2. Scanner data format.

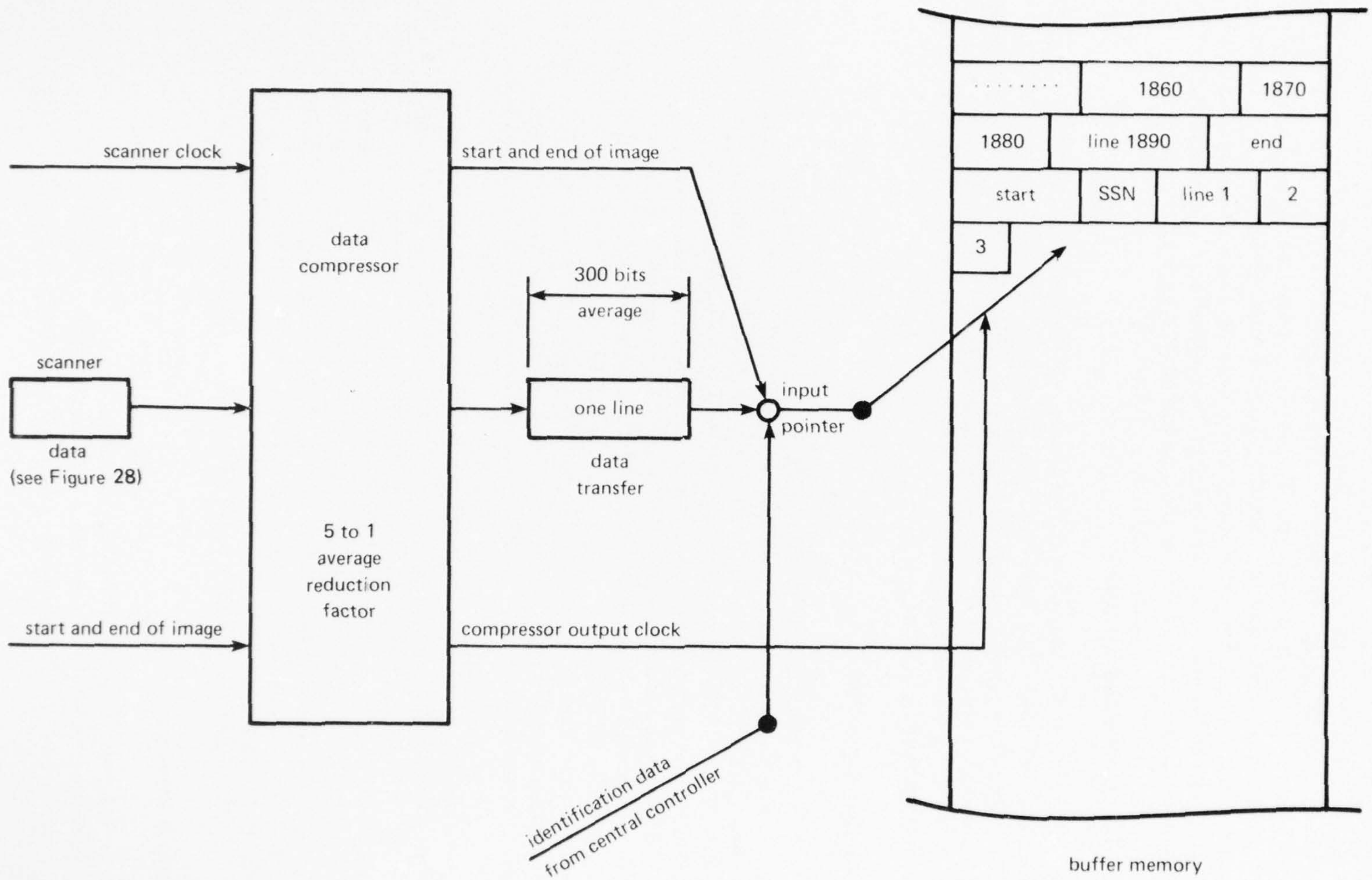


Figure 5.3. Data preparation sequencing.

two asynchronous interfaces. Data must be input from the compressor and merged with the overhead information from the central controller consisting of identification, image packing, and recorder control fields. The maximum input rate of 7.5×10^6 bits per second will be determined by the compressor output. The output interface timing will be provided by the data channel modem at a uniform 250,000 bits per second. The flow of digitized image data is summarized in Figure 5.4. All of the data interface status conditions are transmitted to the central controller for use in the sequencing of the scanner in order to maintain data in the buffer at all times as required to use the data communication link at its capacity.

Data Transmission and Reception

The interface between the buffer and the satellite modem is operated at the uniform data rate under control of the modem clock. Data and clock signals are standard two-level digital information meeting the satellite supplier requirements. At the remote site, a similar interface exists between the satellite modem and the record buffer, and it operates under control of the receiver modem clock. A 250,000-bits-per-second rate is maintained through this data communication link.

Recording Preparation

The remote site buffer memory consists of two functional units. The first is a receiving buffer which accepts data from the communications link modem at a uniform rate and has the capacity of four images in compressed form (2.4×10^6 bits) or approximately 9.6 seconds of data. This memory has a second, or output, interface that supplies data to the expansion (decompression) unit at a rate that guarantees the buffer will never be required to exceed its capacity of four images. Figure 5.5 presents the overall data flow. Timing on the input is controlled by the communications link modem and on the output by the data expansion unit. The second portion of the buffer is used to hold one image in a recorder-ready form as output from the expander. Input to this unit is under control of the expander and will be at a nonuniform rate dependent upon the statistical variation in the original image pixels. Output to the recorder will be under control of the timing signals it generates.

The data expander, which converts the raw compressed data stream into a recorder-compatible format operates between the two portions of the remote site buffer. As part of this task, the identification and control information (i.e., name, SSN, location of eye-readables, etc.) that was incorporated into the data must be extracted and routed to the local controller. Input and output data rates for the expander are asynchronous and control the respective interfaces with the two buffers, while the third interface with the local controller also operates independently. Through-data rates for the interfaces are at reasonably high value to minimize the possibility of exceeding the capacity of the receiving portion and to hold down the delay of the recorder after it has moved to a new image location.

Records Recording

When the control information extracted from the data indicates that an eye-readable category designator is to be recorded, the second buffer is not loaded directly from the expander output. In these circumstances, the recorder-ready form of the eye-readable image

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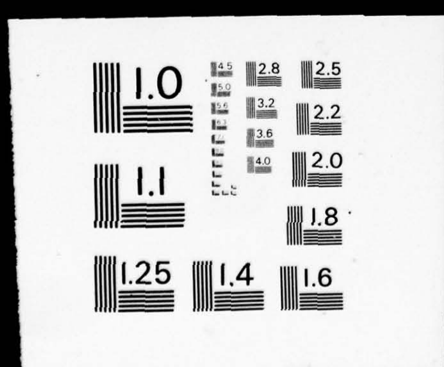
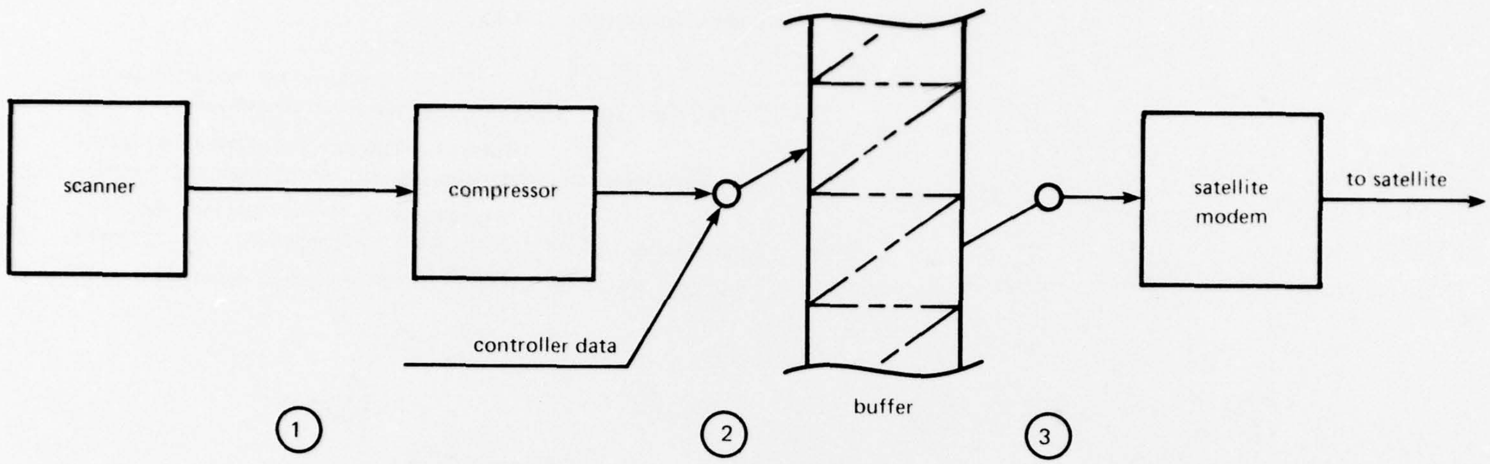


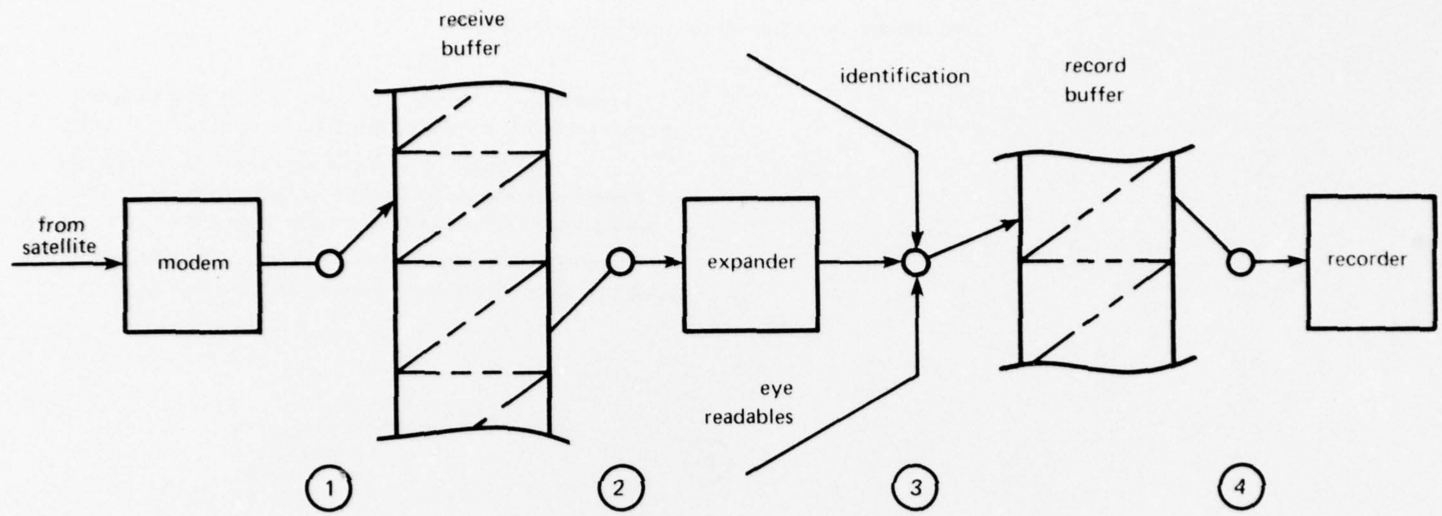


1 On command from controller, scanner will transfer, in a burst, one image field of data to the compressor (see Figure **28**).

2 Data *from scanner* is compressed and merged with overhead data from controller, using timing signals from compressor to control buffer loading pointer (see Figure **29**).

3 Buffer is emptied under control of modem timing signals at a uniform rate. Output pointer is monitored by controller.

Figure 5.4. Digitized image data flow: scanner site.



1 Modem fills buffer at uniform rate under control of modem clocking.

2 Expander, *upon command from controller*, first transfers and expands one image field from receive to record buffer.

3 Identification information if merged with image data. Controller may supply eye-readable image to fill record buffer.

4 Recorder first transfers one image field from buffer. Initiation and timing under recorder control.

Figure 5.5. Digitized image data flow: recorder site.

field is provided from a separate special-purpose generator under direction of the local controller. Simultaneously, the data from the transmission link must be held in the first portion of the buffer with the expander idle until the designator image has been recorded.

Responsibility for the fiche index and image-to-image translation of the recorder is held by the local controller which has the control information extracted from the data. Image packing, the number of images per fiche, and number of fiche in an individual file are under this macrolevel control. Details of the scan within an image field during recording are inherent in the design of the mechanism, and this is the controlling element for data transfer from the recorder buffer.

CENTRAL SITE CONTROLLER

This section describes the central site controller, the single component with overall system coordination responsibility. Since this controller oversees the total operation as well as the central site hardware, it is more complex than the remote site controller described in the next section.

Functional Overview

The central site controller is responsible for the overall coordination of the system functions in order to provide a uniform flow of data and to use the expensive data transmission channel most efficiently. This task is expanded into six specific subefforts in the preliminary design and each of these is examined in terms of the hardware, software, and communication requirements. These individual items are now covered, followed by the integration of the overall design requirements into a set of parameters for the central site controller. The system operating hardware communication is shown in Table 5.3.

Table 5.3. Central site controller.

	Signal Flow	
Operating Device	From Device	From Controller
Request modem	Request identification	Verification; audit information
Printer		Pull Lists; identification labels
Duplicator	Status only	
Prescanner	Blank images; fiche identification	
Scanner	Scanning/done	Start; feed; index
Compressor	End of image	
Buffer	Load location; Dump location	Fiche identification; eye-readable codes
Communication	Status only	
Modem		

Note: All central site unit communicate fault detection and failure status to controller for monitoring and display.

Detailed Discussion of Controller Functions

Request Compilation and Verification. When requests are transmitted from the remote sites, they must be demodulated and entered into the controller memory. This will require a standard design serial data interface operating under interrupt control and a main memory capacity large enough for storing the requests. Requests for a full day from a

remote site would require a memory of 6×10^4 bits. However, the operating plan calls for a dump of the tabulated requests 8 to 10 times per day, which proportionally reduces the holding capacity needed. Software supporting the compilation would only consist of conventional interrupt service input routines and an algorithm for ordering the pull list.

The verification operation is designed to operate in an interactive manner with the request entry of the remote site. When a request is entered, the operator will wait for a response from the central site indicating the validity of the data. This feature will require a full duplex interface with the request link modem and a high-speed mode of access to a data base containing the identification of all files in storage. A standard twenty-surface disc memory is currently used for this storage. If a duplicate of the MPRS data base is maintained, a disc controller interface with supporting software will be required. If maintenance of a copy disc was required, the system software would need to support this function in addition to the disc driver routines.

Operator Hard Copy. Three items of information are generated by the controller in a hard-copy or printed format for use by the system operators. The first is in the form of pull lists printed on a regular basis to specify those master files that are to be withdrawn from storage for duplication. Secondly, identification labels that contain a machine-readable code must also be printed for each file that is to be pulled and duplicated. Both of these printed forms are produced on conventional computer output printers with, perhaps, a special typeface. The data for each of these printings are from the ordered list of requests held in the controller's memory and require a minimal amount of additional programming beyond the output routines of the printer control. Operator messages, maintenance information, calibration, and testing aids form the third class of printed outputs. These messages would be printed on an operator's console used for the direction of the controller's operation. The software for this function would be contained in the operating system package.

Image Packing. The information transfer required to accomplish the image-packing task includes the following:

1. Input of blank image field data from the prescan station along with the file identification

2. Output of image-to-image index commands to the scanner

3. Output of file identification, image location, and eye-readable identifier locations to the buffer memory.

From the prescan information and knowledge of the fiche order in the file, and the standard formats and category locations, the packing algorithm may be satisfied. All of this information is available after the prescan. The most efficient sequence to scan the images and the locations of each image and identifier on the resulting output fiche are determined by the controller.

Direct commands will be sent to the scanner from the central controller indicating when to step along a line or down a column and when to eject one fiche and load the next. The digitized image data from the scanner are compressed and presented for storage in the buffer memory. At the buffer input, the additional data necessary for identification of the images are provided by the controller.

Software in the image-packing function must include input-output routines for the three device interfaces that will operate on an interrupt basis in response to the device cycles. Implementation of the actual computational portion of the packing algorithm and identifier placement task involves only simple computational operations. These routines will operate concurrently in the required real-time environment imposed by the scanner.

Data Formats. Before transmission, the digitized image data generated by the compressor must be placed into a format usable by the remote site recorder. In addition to the eye-readable identifier provided by the packing algorithm, the identification information for the record must be included. Some control data for the record must also be provided such as the number of fiche in the record, the number of images, an end-of-fiche indicator and a feed command.

Statistical variations in the compressed length of each image field will require that the controller receive data from the compressor to determine the status of the data. Signals indicating the end of an image frame will be the minimum required information. The location at which additions to the data are to be made is available from the image-packing software. Timing will be in an interrupt mode response to the compressor signals.

Synchronization. Maintaining a continuous flow of data through the satellite link is the central controller task most directly impacting the overall system efficiency. For both reliability and economy, it is desirable to maintain the data flow with a minimum amount of buffer memory. This can best be accomplished by reducing the latency of all the system components, that is, by making them respond rapidly to demands for data. The satellite link requires data at a continuous uniform rate, but data enter the system in the form of images on fiche, where the number per fiche may vary from 1 to 98. A design worst case is four sequential fiche with one image each. In this arrangement, a maximum of overhead time involved in fiche handling would slow the data rate to a minimum.

Of major importance to the controller's synchronization task is the organization of the buffer with its independent input and output ports. These ports have separate pointers indicating the locations in the buffer currently ready to be input to or output from, and their values are available to the controller. The capacity of the buffer is approximately four images in compressed form.

The synchronization task, illustrated in Figure 5.6, is accomplished as follows:

1. The channel demands data at a uniform rate, causing the output pointer to scan through the buffer address space.

2. The controller monitors the values of the input and output pointers.

3. When the output pointer is one image field ahead of the input pointer, indicating space for a new frame, the controller commands the scanner to start.

4. The scanner and compressor will produce one image field in one-fifth the time required for the output of the next field. See Figure 5.2.

5. Immediately upon completion of the scan, the scanner is commanded to the next image space on the fiche.

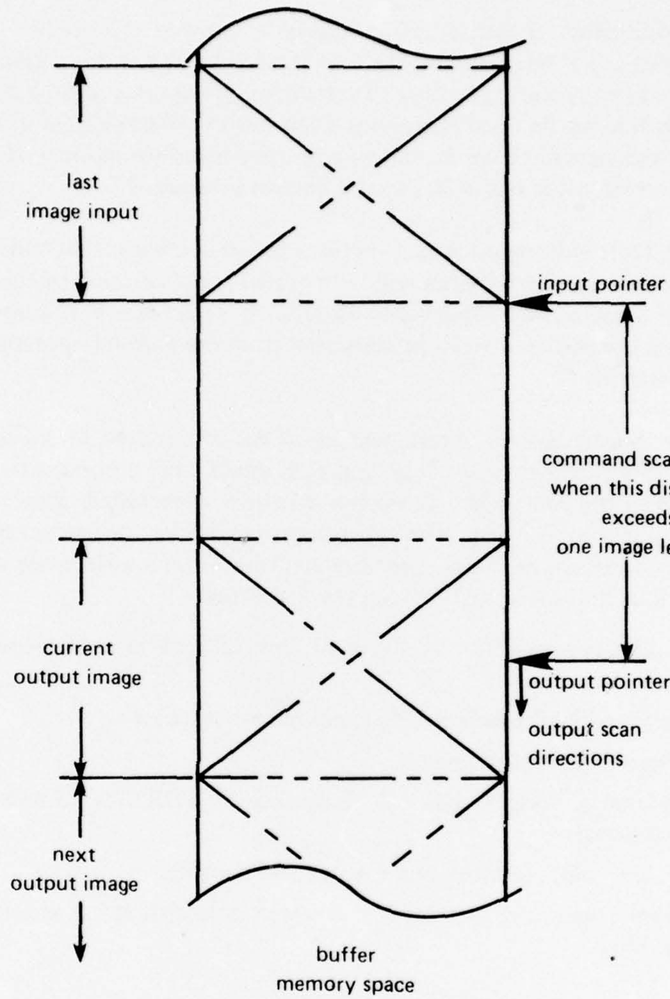


Figure 5.6. Scanner synchronization algorithm.

6. If the last image has been scanned, the fiche is indexed. The first frame on the new fiche must then be located. This maximum time is three-fifths of the image output time.

7. If the worst case occurs, the images will be produced in four-fifths of the time they are output.

8. One frame of the buffer is empty at the command to scan; one is emptied to 20 percent of capacity during the scan; a third must be full, as it is needed at the end of the scan. This requires three full frames of storage: one input, one output, and one ready.

9. The statistical variation in frame lengths after compression requires one additional frame of buffer for security. Thus, four total frames are required.

Direct numeric comparison of the buffer address pointers is the only computational requirement for the controller imposed by the synchronization task. Location and index commands for the scanner are available from the image-packing task. An interface must be provided for the buffer address pointers; it is the only hardware requirement.

Status Monitoring. A central status display is included as a portion of the controller hardware to present at a single location the data needed by the system operator for monitoring the status of all the operating devices. Each device is required to provide the controller with the signals indicating its condition, even if the individual device incorporates a status indicator. These signals will be connected to a priority interface module of the controller. No communication from the controller to the devices is required.

Warnings, fault indications, and directions for corrective action will be displayed on the operator console. Service routines will be required for evaluation of the status signals and for output of the specific messages and directions. This console will also be the input device for entering the status or audit information from the manual operations such as searching the master files.

Controller Specifications. From analysis of the procedures described above, the system requirements for memory, interfaces, and equipment were compiled to yield a preliminary specification of the controller. These requirements were tested against the performance available from commercial devices. The capability required by the system controller at the central site in this preliminary design is readily available from a wide range of standard sources. The various items required include the following:

1. Central Processing Unit: 16-bit word, 2-mHz clock rate; high-speed interrupts, priority modules
2. Memory: 64,000 words RAM; direct memory access
3. Peripherals: operator console
4. Mass Memory: system disc – single surface, BUPERS MPRS data; base disc – twenty surface (optional)
5. Interfaces: data, control, and status to all devices
6. Software: operating system, device service routines, status monitoring, maintenance and calibration.

REMOTE SITE CONTROLLER

Functional Overview

At a remote site, the controller functions are mainly reactive in nature as the system responds to the uniform flow of data received over the satellite link. Three separate subtasks are to be performed at a remote site: receive buffering, image data expansion, and facsimile recording. Each subtask was evaluated in the preliminary design study. Results from the individual tasks collectively define the overall requirements for the remote site controller. The operating devices at a remote site and the related hardware signal flows are shown in Table 5.4. Resolving the asynchronous character of these signals while using a minimum of buffer memory is the overall design goal of the controller as implemented in the following procedures.

Table 5.4. Remote site controller.

Operating Device	Signal Flow	
	From Device	From Controller
Request Terminal	Status Only	Status Only
Request Modem	Status Only	Status Only
Communication Modem	Status Only	Status Only
Receiver Buffer	Load location; Dump location	
Expander	Fiche I.D.; packing data; eye readables	Start
Recorder Buffer		Eye readables
Recorder	Recording/done	Start; index; feed

Note: All remote site units communicate fault detection and failure status to controller for monitoring and display.

Detailed Discussion of Controller Functions

Data Formats. Included along with the digitized image information in the data stream received by the link modem is all of the identification and control information. This additional information is extracted from the data at the buffer expander interface and fed to the controller. Control of this transfer is by interrupt service software responding to timing signals from the expander.

Fiche identification information is used to control the recording of headers on the fiche and is output to the recorder as control information. Additional control information is output to the recorder to direct the image-to-image indexing and the feeding of new fiche. An output interface is also required to the recorder buffer so that the eye-readable identifiers may be loaded into the buffer when indicated by the control codes in the data streams.

Only input and output service routines are needed for these operations. A very minimal processing load is involved in the software, and the timing requirements are easily satisfied.

Synchronization. As was the case at the central location, the controller has the task of resolving the asynchronous operation of the system components with the uniform data rate of the satellite link. For the remote site, the input is at a uniform rate and the processing variations introduce the timing problems. A design goal is to minimize the buffer memory requirements.

The sources of processing variations occur at several places in the system. Recorder indexing and feed times are one major source of delays, and the statistical variation in the length of an expanded image field is another. The worse case perturbation of the data flow for design purposes was taken to be the need to insert an eye-readable identifier at alternate image locations for four consecutive operations. This operation involves the receiving buffer, data expander, and recording buffer, as well as the recorder itself. Both buffers have input and output pointers whose values are available to the controller. The receiving buffer has a capacity of four images, and the recorder buffer can hold one image field in expanded form. Figure 5.7 shows the synchronization relationships.

The following tabulates the synchronizing task procedure:

1. The channel supplies data at a uniform rate, and the input pointer scans through the buffer address space.

2. At any instant where one full image is in the receive buffer and the record buffer is empty, the controller commands the expander to start.

3. The expander transfers one image field in one-fifth the time required to fill the receive buffer.

4. If the record buffer is full and the recorder is idle, the controller commands the recorder to start.

5. The recorder produces an image field in one-fifth the channel transfer rate.

6. At the end of record, the controller commands image location indexing which takes one-fifth of the channel frame time. Simultaneously, the record buffer may be filled if an image is available.

7. In the worst case, the next image field will be an eye-readable, and no data will be removed from the receive buffer. This field is recorded, and the recorder indexed, taking a total of two-fifths of a cycle.

8. With alternate eye-readables, images are pulled from the receive buffer in four-fifths the time required to load them.

9. One frame of the buffer is being filled, one frame is ready to dump, and one is waiting to be filled. The fourth frame accounts for variations in field length and the time for feed of new fiche.

The interface requirements for this task are comparable with the corresponding central site task. While twice as many interface ports are present with the two-part buffer, the actual values of the address pointers are not required. The communications rates required are well within the capacity of commercial processors.

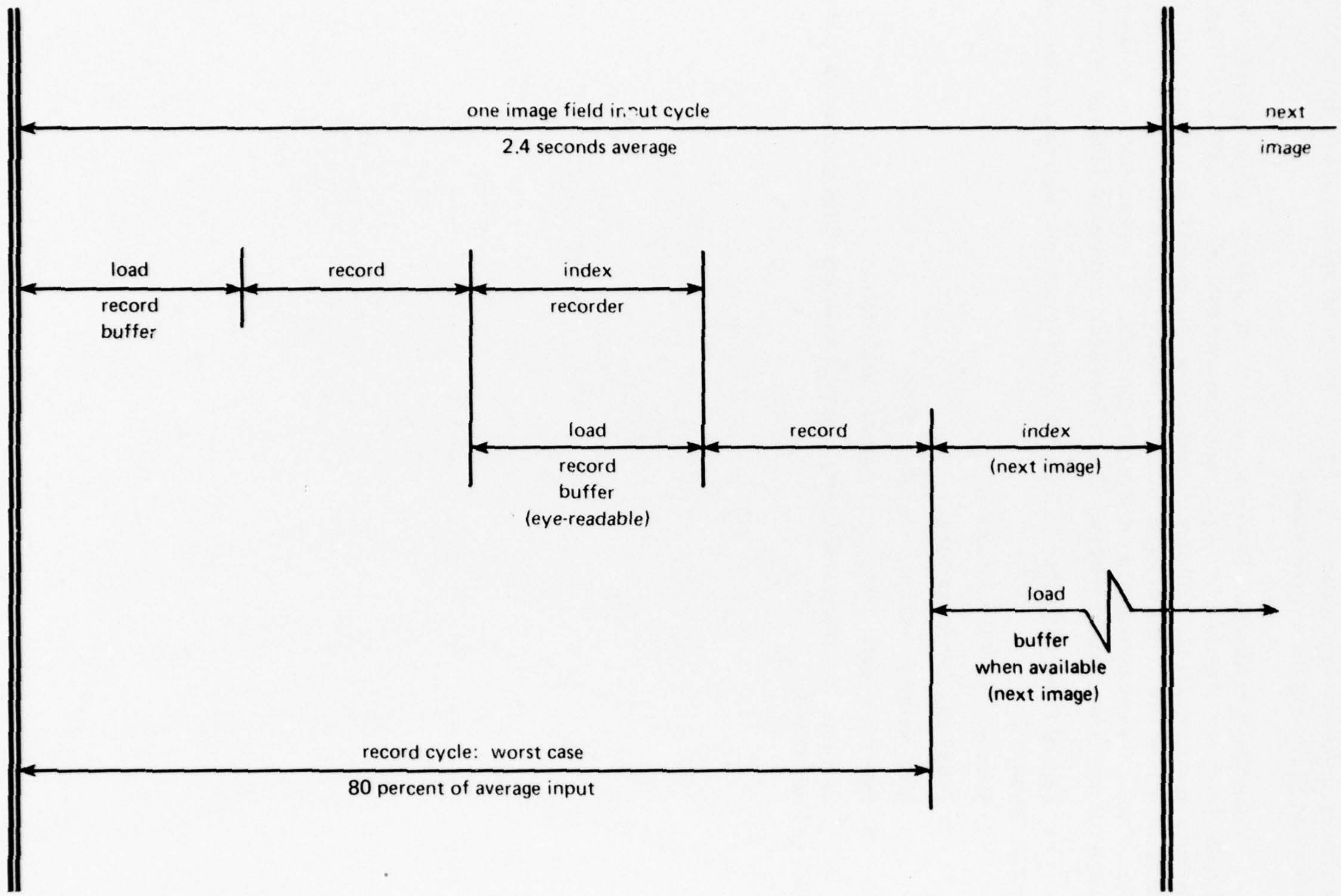


Figure 5.7. Recorder synchronization.

Status Monitoring. The requirements at the remote site for monitoring the status of the system components for display at an operator's terminal are identical in nature to the corresponding items at the central location.

Controller Specification. Processor, memory, and interface requirements for the subtasks above were organized into a preliminary system controller specification. These performance characteristics and hardware elements are widely available as commercial items. The entire remote site controller function might possibly be incorporated, with the addition of interfaces and some memory, in the recorder controller, if a general-purpose processor is used in the particular recorder selected. The various items required include the following:

1. Central Processing Unit: 16-bit word; 2-mHz clock rate; high-speed interrupts, priority modules

2. Memory: 32,000 words RAM

3. Peripherals: operator console

4. Mass Memory: system disc – single floppy

5. Interfaces: data, control, and status to all devices

6. Software: operating system, device service routines, status monitoring, maintenance and calibration.

RELIABILITY AND MAINTAINABILITY

A highly reliable system is necessary for an MITS to handle the large number of records requests anticipated. In addition, ease of maintenance must be an important design criteria because extensive down time will create major backlogs in transmission. The major components were studied for the mean-time-between-failure (MTBF) values, periodic maintenance requirements, and average repair times. Estimates were made of the overall system performance in these areas based upon the following assumptions:

1. The system operates 20 hours per day.
2. Four hours per day are allocated to routine maintenance and repair without compromising the system task at full capacity.
3. All devices are designed with state-of-the-art, integrated electronics components in modular replacement units.
4. Spares and service personnel are available.
5. Diagnostic support programs can rapidly isolate failed modules.
6. Infant mortality effects for the system and individual devices have dissipated.
7. Only hard failures are significant, and noninterfering recovery techniques are available for other failure modes.

Since the system elements are performing in the standard design modes which they would experience in any operating environment and are not subjected to abnormal stress, the available reliability data may be used. It is also assumed that the failures are independent and the maintenance requirements are additive. Estimates available in the literature for both the scanner and the recorder devices give values near 2,000 hours MTBF. A modern digital computer with the number of peripherals used in this system has an MTBF estimate at close to this same figure. System integration of these should have a negligible effect as all interfaces will be of standard types.

The estimates of the MTBF of the system, independent of the communication link, is 1,200 hours determined from

$$\text{MTBF} = \frac{\sqrt{N}\, M_1 M_2}{M_1 + M_2} \times S$$

where

N = number of elements (2),

M = MTBF of element i ($M_1 = M_2 = 2000$), and

S = system factor (88 percent)

For all failure modes, including the hard failures above, the average yearly maintenance requirements are estimated to be less than 300 hours per year. This is well within the available total time, and, because of low estimated time to repair resulting from the modular design, the time will be favorably distributed. From the consulted survey data on the candidate scanners, the scanners are estimated as requiring from 80 to 120 hours of this total time. The remainder of the time is distributed in the controller (100 hours) and the man-machine terminals.

SUMMARY

A preliminary hardware system design for MITS has been completed. This design was based on the major components selected as a result of the options analysis. The data flow for each component is described from the perspective of how it communicates with the other components and the system controllers. Using worst case configurations of images on the microfiche and with a fundamental requirement to use the lowest possible bandwidth for a transmission link, specifications for input and output from each component were determined. The scanning and recording data rate design maximum is 7.5×10^6 bits per second to achieve an average transmission time of 2.4 seconds per image. This allows transmission of 300 records in a 20-hour period. A complete record of 4 microfiche carrying a total of 100 images can be transmitted in 4 minutes for a priority transmission. Total turnaround from record request to copy fiche distribution can be less than 1 hour.

REFERENCE

5.1 Naval Undersea Center. NUC Technical Note 1756, Electronic Interfacing and Detailed Design Consideration for the Bureau of Naval Personnel's Microfiche Image Transmission System (MITS), by K. Drake December 1976.

6. SYSTEM DESIGN: HUMAN FACTORS

INTRODUCTION

The human factors engineering for MITS directly supported the preliminary system design. The previous section was directed to the hardware requirements for MITS. The requirements and specifications for all automated functions were presented. However, as mentioned in the introduction to this system design section, hardware is only half of the system. The purpose of this section is to present a summary of the results of the MITS human factors engineering task. A detailed discussion of this effort is presented in Reference 6.1. All manual and man-machine procedures necessary to implement a microfacsimile system are identified and defined. Automatic functions which require no human interaction were covered entirely in the previous section. Central and remote site workflow and work station configurations are also presented. Finally, as an example of the trade-offs encountered in remote site selection, the specific location for the San Diego remote site office is selected

The primary objective of the human factors task was to establish basic position descriptions (PDs) for the personnel required to operate MITS and to state the minimum number of operator and supervisory personnel required for each site. In addition, the task addressed two secondary objectives. The first was to analyze, by means of an independently designed and executed experiment, the feasibility of using a new microfiche record format as the MITS output instead of the current standard format. The proposed MITS output format is the image-packed format which was discussed earlier in this report. As the earlier discussion was quite complete, the image-packing aspects of the human factors task will not be repeated here. The other secondary objective was a site survey of the 11th Naval District designed to identify a potential location for the San Diego remote MITS site. San Diego is a leading remote site candidate for MITS because of its large concentration of Naval personnel and because it represents an engineering convenience should the MITS prototype system be constructed under the cognizance of the Naval Undersea Center's MITS task team.

APPROACH

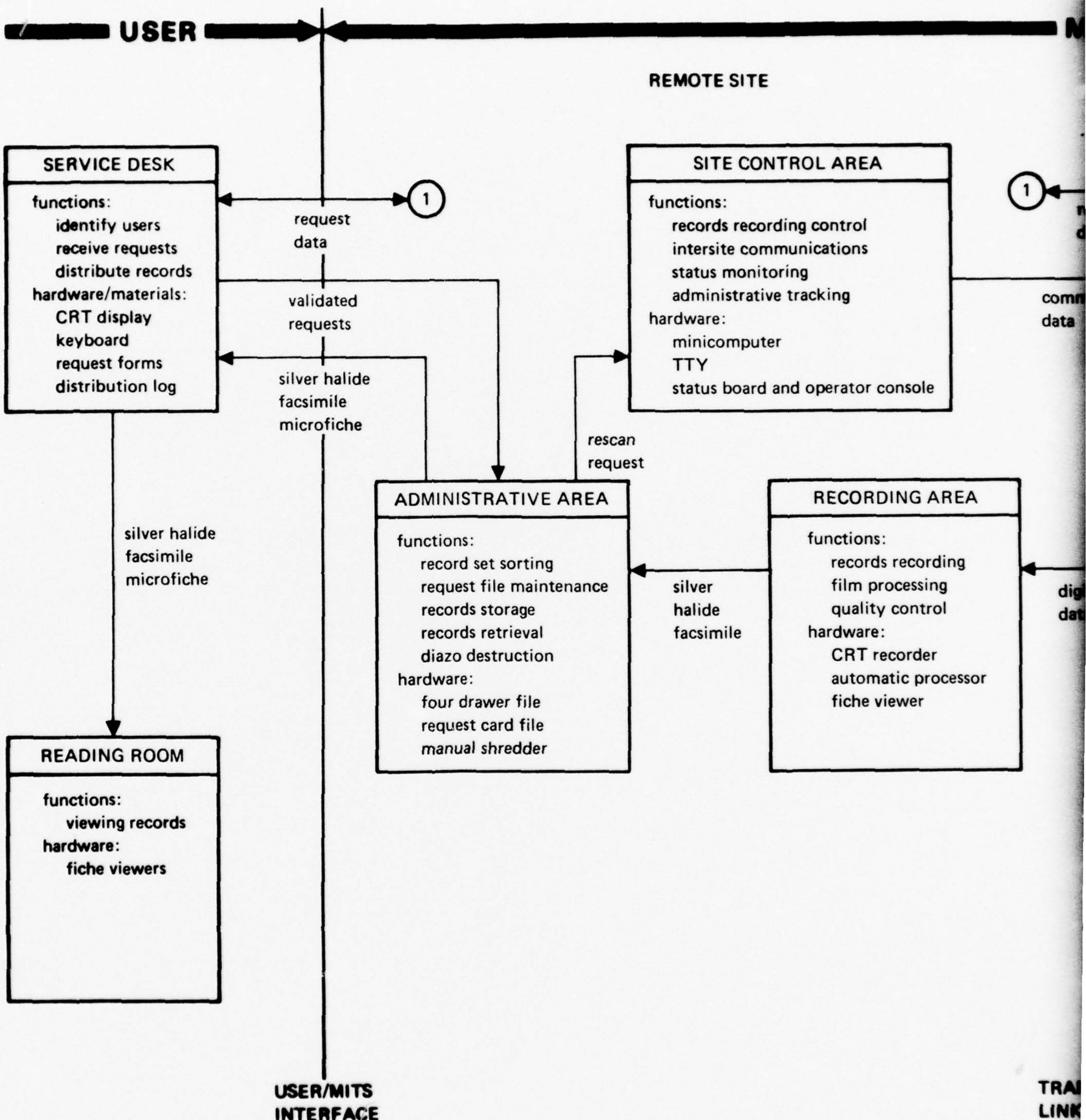
This section discusses the basic approach taken to satisfy the requirements described above. The emphasis of the human factors engineering task was at the systems level. Components were analyzed at functional and workflow levels. However, no attempt was made at this early stage of the system design to suggest equipment modifications for improved man-machine interfaces. Although all system components have been selected, many will be specially configured to MITS specifications. These specifications have not yet been written. Also, work procedures cannot be completely evaluated until tested in actual operational conditions. It is anticipated that these efforts will be accomplished during the MITS final design and prototype phases.

Familiarization and Overview

Since human factors support entered the design cycle subsequent to early system conceptualization, initial efforts were devoted to obtaining a thorough working knowledge of MITS as then conceived. A modified functional block diagram, Figure 6.1 was produced to identify and categorize all of the MITS man-machine interfaces and to familiarize the human factors engineer with particular system procedures and equipment. Based on this diagram and the basic MITS design goals, preliminary position descriptions (PDs) were prepared. These PDs included costing and manning estimates. In a parallel effort, small-scale mockups of proposed Central and Remote MITS facilities were constructed and analyzed for best workspace arrangement. All available MITS data including the original proposal, feasibility study report, progress reports, program plans and correspondence, drawings, and hardware specifications and documents, were reviewed to reach a thorough understanding of the conceptual system. The requirements for any constraints upon the proposed system were identified. The MITS mission and operational environment were examined, in particular those factors involving man-machine performance.

Man-Machine System Analysis

In actuality the human factors engineering task combined several analyses which in a larger, less well-defined system would have normally been accomplished separately. These included (1) defining and allocating system functions, such as identifying automatic operation/maintenance, manual operation/maintenance, or some combination thereof; (2) determining basic information flow and processing without reference to any specific machine or human involvement; (3) estimating potential operator/maintainer processing capabilities by identifying plausible human roles and estimating capability in terms of load, accuracy, rate, and time delay for each operator/maintainer information processing function; (4) allocating functions by determining which system functions are best assigned to the machine and which to the operator/maintainer given operator performance and cost constraints; and, finally, (5) performing a gross task analysis as the basis for making design decisions, among which are preliminary manning levels, equipment procedures, skill training, and communication requirements.


USER
REMOTE SITE
SERVICE DESK
functions:
identify users
receive requests
distribute records
hardware/materials:
CRT display
keyboard
request forms
distribution log
request
data
validated
requests
silver halide
facsimile
microfiche
1
SITE CONTROL AREA
functions:
records recording control
intersite communications
status monitoring
administrative tracking
hardware:
minicomputer
TTY
status board and operator console
rescan
request
ADMINISTRATIVE AREA
functions:
record set sorting
request file maintenance
records storage
records retrieval
diazo destruction
hardware:
four drawer file
request card file
manual shredder
silver
halide
facsimile
RECORDING AREA
functions:
records recording
film processing
quality control
hardware:
CRT recorder
automatic processor
fiche viewer
silver halide
facsimile
microfiche
READING ROOM
functions:
viewing records
hardware:
fiche viewers
USER/MITS
INTERFACE

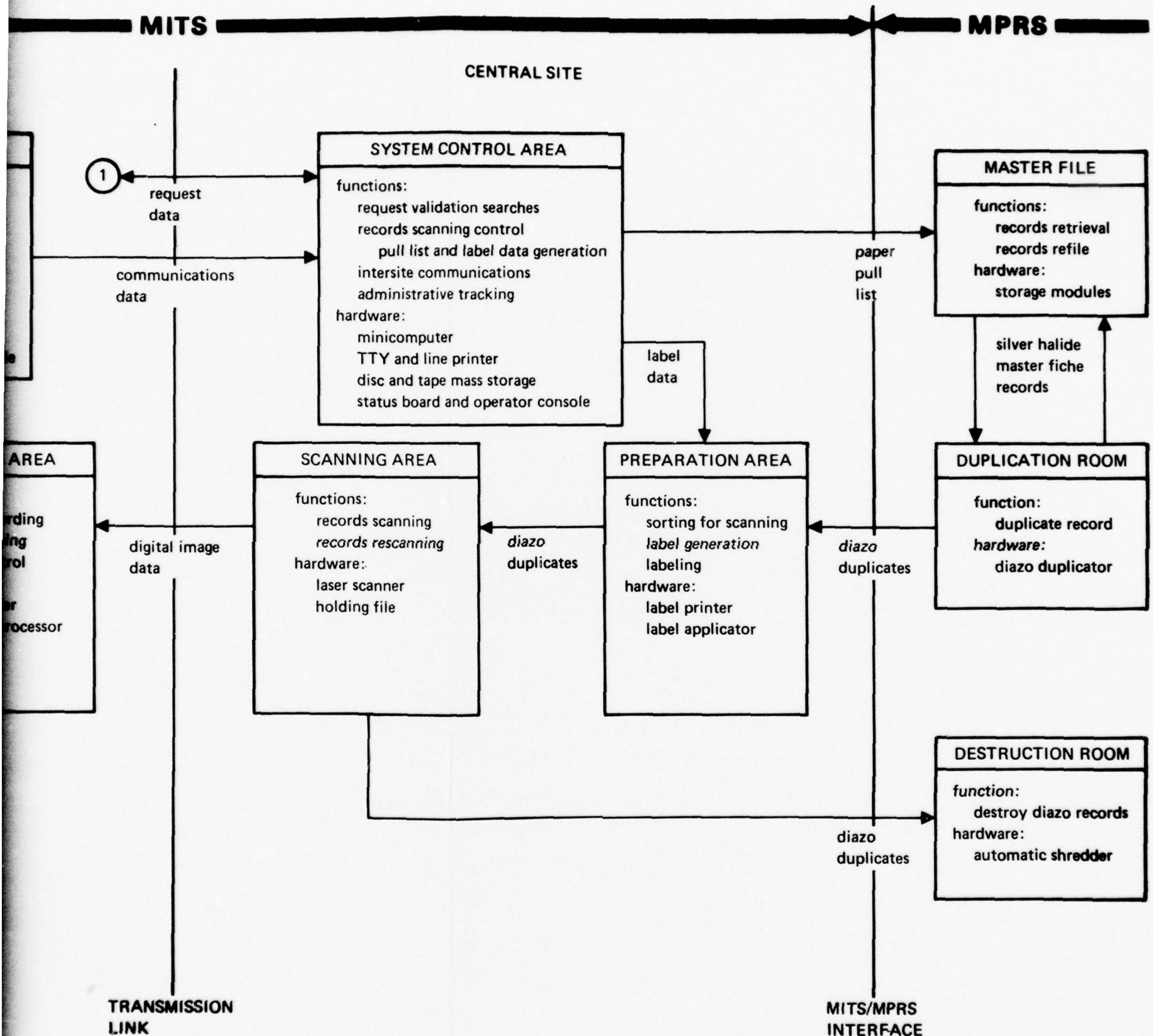


Figure 6.1. Modified functional block diagram with man-machine interfaces.

All of the above briefly stated analyses are formal human factors engineering techniques which, when properly applied, are powerful allies in manned system design. The MITS system, however, is small, not unduly complex, and had already undergone a feasibility study (Reference 6.2) which showed the concept to be within the state-of-the-art. In addition, designated equipment was to be off-the-shelf, which might relieve some of the human engineering pressure. The latter aspect, however, was not taken for granted. Also, at least part of the system was already in everyday operation at BUPERS and would thus provide some working procedures.

RESULTS

Personnel Requirements

Two primary sources were used to determine the personnel requirements for MITS. The first was Figure 6.1, which was presented earlier in this section. This figure was developed from the original functional block diagram of MITS with emphasis on the human and human-machine functions. The second major source of information for determining personnel requirements was documentation for the existing functions which are part of the MPRS at the Bureau of Naval Personnel. Analysis of these sources established five different possible work positions with a total manning requirement of eight people for one remote and one central site over three shifts. Table 6.1 lists the personnel required by position title and GS level. Additionally, the work site and shifts are indicated. Detailed position descriptions were written for each of the personnel and are included in Reference 6.1. A summary of the major duties for each of the positions is included at the end of this report as Appendix B.

Table 6.1. Recommended position descriptions and grade levels for MITS personnel.

REMOTE SITE				
	Shift 1	1.	Principal Receptionist	GS-9
		2.	Production Controller	GS-5
	Shift 2	1.	Production Controller	GS-5
	Shift 3	1.	Production Controller	GS-5
CENTRAL SITE				
	Shift 1	1.	Service Control Supervisor	GS-7
		2.	Production Controller	GS-5
	Shift 2	1.	Production Controller	GS-5
	Shift 3	1.	Production Controller	GS-5

Hours of Operation

As already indicated, both the central and the remote sites for MITS will operate 24 hours a day, over three shifts. In addition to the normal procedures, a 4-hour period will be set aside at each location for routine cleaning and preventive maintenance of the system hardware. The schedule will be arranged such that all remote sites and the central site are conducting this 4-hour preventive maintenance period simultaneously. Figure 6.2 shows the time relationships between three potential remote sites and the central MITS site.

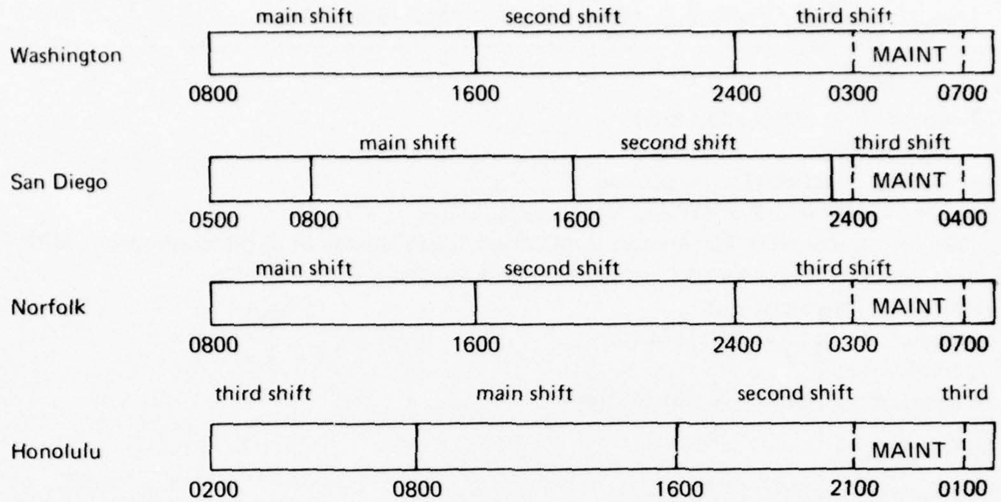


Figure 6.2. Shift scheduling.

Remote and Central Site Office Facilities

After completion of the work already described, the next major step was to establish workable layouts for both the MITS central and remote site offices. Table 6.2 lists the primary design criteria for both sites. The approach to establishing room layouts was to use the NELC model and shop facilities to construct a three-dimensional model of both sites. This technique allowed for several arrangements to be tried, with optimum work flow and user's convenience eventually accommodated. Since any number of arrangements of rooms and equipment may solve a particular work requirement, configuration criteria like those listed in Table 16 were used to limit the number of starting variables. For example, the MITS central site will be located in the building which currently houses MPRS. Since the MITS central site will use several of the existing functions of MPRS (retrieval and duplication of the masters as well as copy fiche disposal) it should be located adjacent to the MPRS service control area. The office layout and dimensions of the MPRS facility are known (26 feet wide); therefore, the width of MITS layout is the same number. Then, using the other criteria and principles of work/maintenance space arrangement, the length and number of rooms in the MITS central site was determined. There is no way to predict the final location of all MITS remote sites. Therefore, since the 26-foot width of the MITS central site is not extreme, that figure was used to layout the remote site as well. Figures 6.3 through 6.6 show both line drawings and photographs of the models. Each of the work spaces and the MITS hardware components and functional areas within the rooms are identified. The area totals are 1500 square feet for the remote site office and 900 square feet for the central site office.

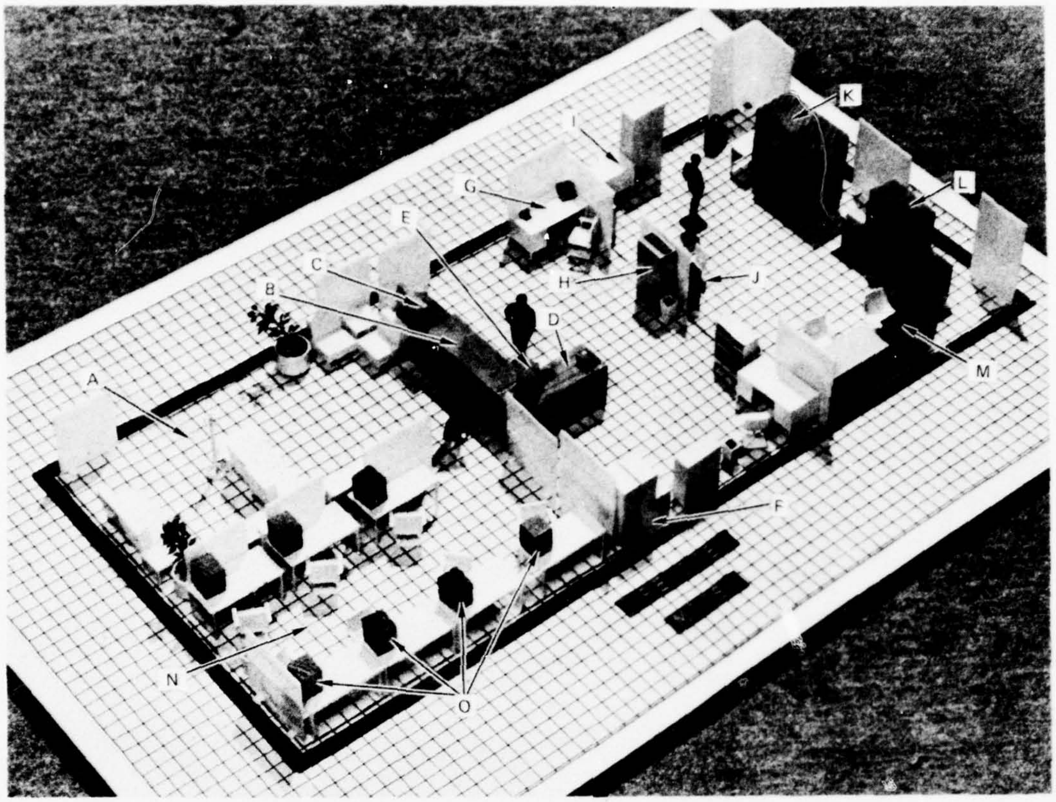
Site Selection

At present, three locations are being considered for MITS remote sites. They are San Diego, CA, Norfolk, Virginia, and Honolulu, Hawaii. In the future, other sites may be added. At each of the sites, it is necessary to select an existing Naval facility as the home of

Table 6.2. MITS office configuration criteria.

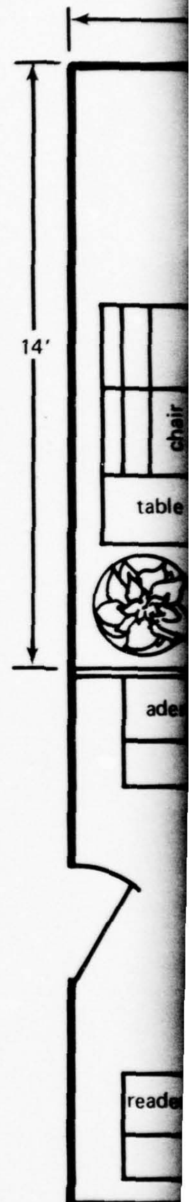
CENTRAL SITE
300 Requests/8 hr. day (1200 fiche)
Minimum manning
Image packing functional areas needed
Tenant, but independent of MPRS, Washington, D.C.
Facilities for master records retrieval, duplication, and disposal of duplicates exist at MPRS
Standard environmental control for electronics is needed
Elevated floor for electronics
Maintenance access to components
Equipment sizing
Noise levels at a minimum in service areas
REMOTE SITE
300 Requests/8 hr. day (1200 fiche)
Minimum manning
Tenant, but independent of local Naval facility
Standard environmental control for electronics
Elevated floor for electronics
Maintenance access
Equipment sizing
Noise levels at a minimum in service areas
Viewing room available
Waiting room available

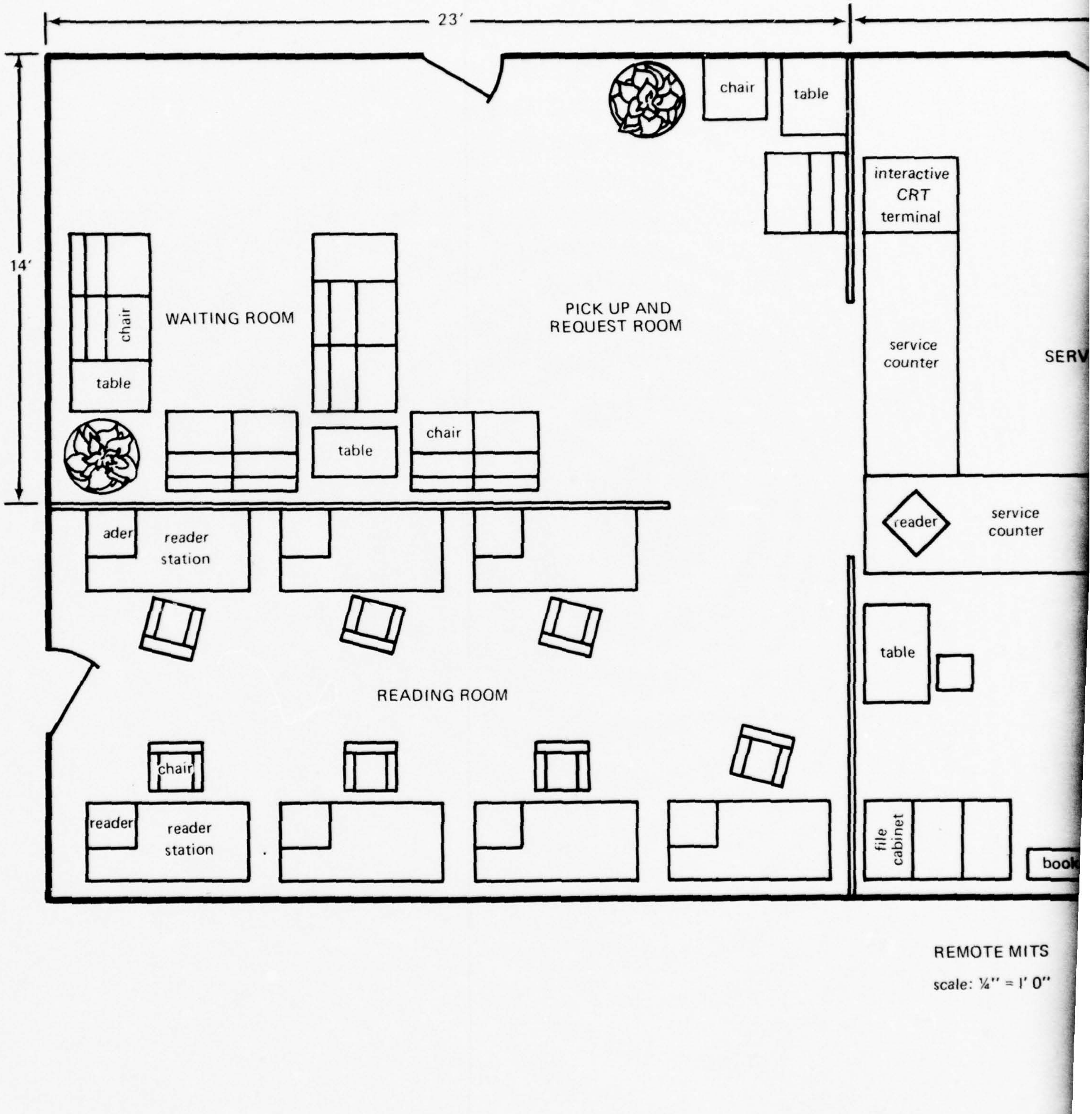
the MITS remote site request office. As an example of the procedures which must be followed and an indication of the tradeoffs involved, a Naval facility was selected for the remote site office which is to be located in San Diego. San Diego county has numerous Naval facilities located within the city limits and in nearby unincorporated areas. The size of these Naval facilities varies greatly in terms of the number of personnel within the command and the land area occupied by the facility. In addition, there are variations in the proximity of one station to another as well as the density of station within certain geographic regions. These, as well as other factors, suggest tradeoffs and options to be considered before a suitable site is selected. Two main criteria for the selection of a remote site location for both the MITS data link earth station and the request office were considered. They were (1) convenience to the requester and (2) convenience to the technical community which will operate the system. Obviously, of primary importance is service to the user. The details of the tradeoffs considered and the results of their analysis are listed in Reference 6.1. The analysis resulted in the selection of the Naval Station at 32nd Street as the host activity for the MITS remote site in San Diego. This site provides the greatest convenience and access to the largest number of Naval personnel in San Diego.



A. Waiting room
B. Service counter
C. Interactive CRT terminal
D. Record file
E. Mini-Cats reader
F. Administrative files
G. Desks
H. Safe
I. Workbench and storage
J. Fiche shredder
K. Recorder
L. Minicomputer, electronics racks, disc drive
M. Teletype
N. Reading room
O. Minicals readers

Figure 6.3. MITS remote site model.





REMOTE MITS

scale: ¼″ = 1′ 0″

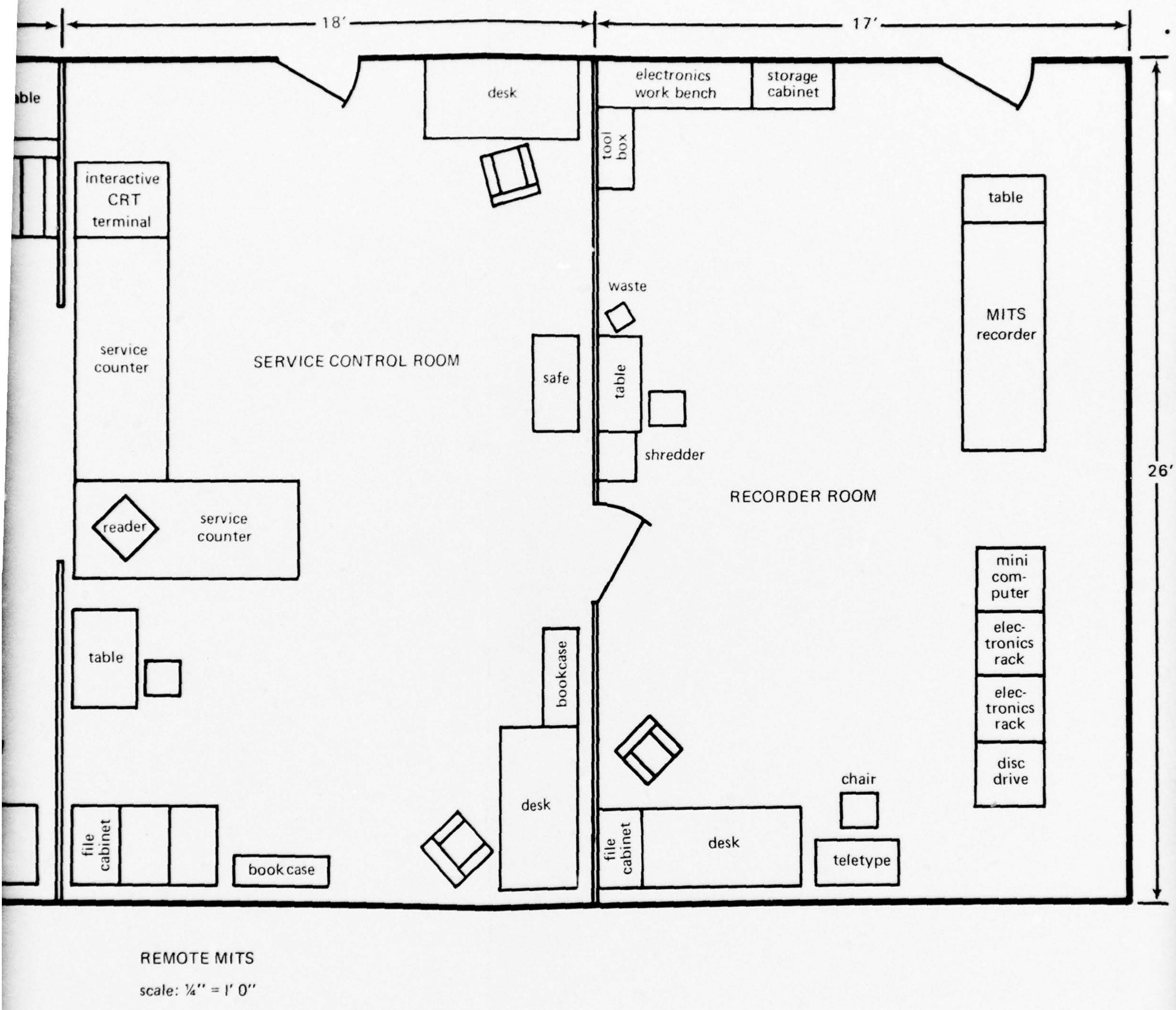
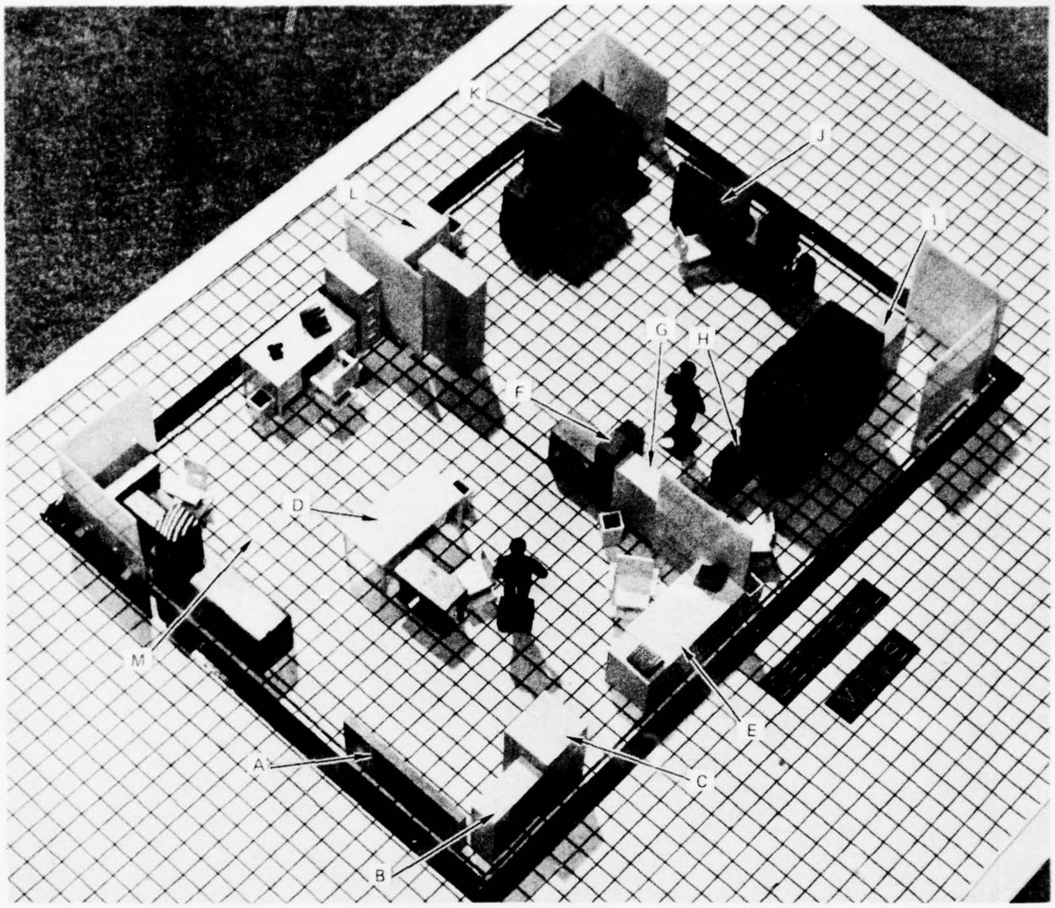


Figure 6.4. MITS remote site floor plan.



A. Window counter next to MPRS

B. File storage

C. Safe and administrative file

D. Sorting area

E. Desks

F. Labeler

G. Input file

H. Scanner input bin

I. Output file

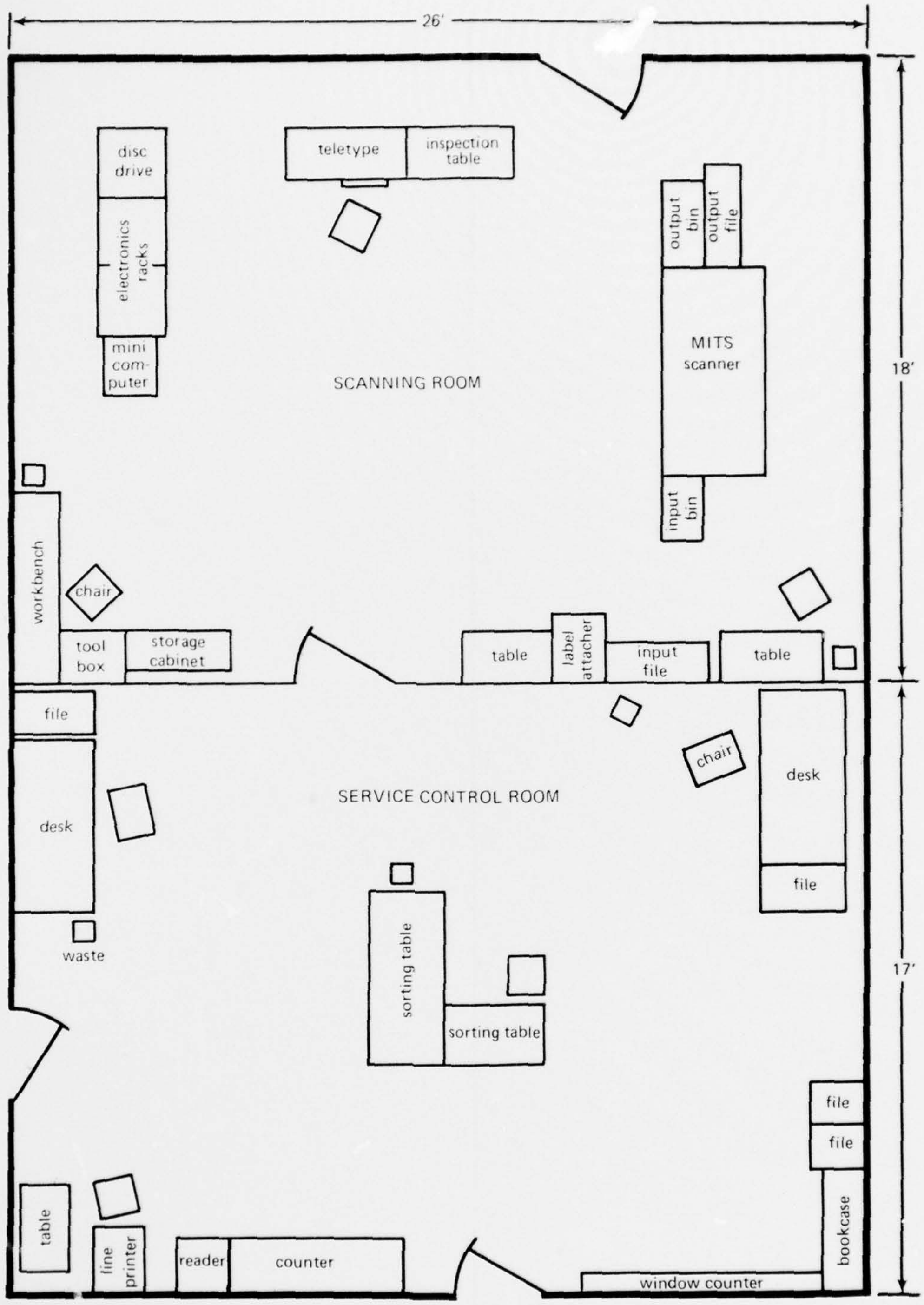
J. Teletype

K. Minicomputer, electronics racks, disc drive

L. Workbench, parts storage

M. Administrative work area

Figure 6.5. MITS central site model.



MITS CENTRAL

scale: ¼" = 1' 0"

Figure 6.6. MITS central site floor plan.

SUMMARY

No attempt was made to analyze the human engineering characteristics of the controls and displays of the particular MITS components. This should be done at a later date when procurement specifications are being written. Much of the equipment identified for MITS is available in standard off-the-shelf configuration. For example, teletypes and interactive terminals have already been human-engineered. That is not to say that the specific models selected as MITS components should not be analyzed for good human engineering characteristics. This should become a part of the selection criteria. Some of the more unique system components such as the recorder and scanner may represent one-of-a-kind hardware or may be modified in order to perform the MITS task. They will require careful human engineering and evaluation. However, at this point in the MITS system design, such an evaluation is premature.

All manual and man-machine procedures necessary to implement MITS have been identified and defined. The personnel requirements for a single remote-terminal three-shift operation MITS have been established, with a total of eight persons required. The specific skill levels and position descriptions are presented in summary form in this section. A more detailed version is included in Reference 6.1. Suggested layouts for both the central and remote MITS sites have been produced. In addition, a specific host facility has been selected for the San Diego remote MITS site.

REFERENCES

6.1 Naval Undersea Center. NUC Technical Note 1755, Human Factors Considerations for the Bureau of Naval Personnel's Microfiche Image Transmission System (MITS), by L. Hufford. December 1976.

6.2 ______. NUC Technical Note 1562, Microfiche Image Transmission System (MITS) Feasibility Study for the Bureau of Naval Personnel, by B. Saltzer, C. Morrin, D. Griffin, D. Solarek. June 1976.

7. PROTOTYPE IMPLEMENTATION

OVERVIEW OF NEED

A demonstration of the efficiency and reliability of an operational MITS is desirable prior to implementation of a full-volume, multiterminal MITS. A single-link system established between Washington, D.C., and San Diego, for example, can serve as an evaluation tool and eventually become a fully operational channel in the final system. With the construction of this prototype system, capital expenditure is minimized by avoiding a complete system acquisition; however, all critical operational procedures and equipment can be tested, refined as necessary, and demonstrated as fully acceptable for handling the BUPERS workload. In addition, the estimated user volume (300 records requests per day) can be verified or updated from actual operations. Thus, the system can be demonstrated at the same time projections for the user demand are confirmed.

RECOMMENDED PROTOTYPE DESIGN

The prototype specifications are the same as those for the preliminary design described in Section 4. Table 7.1 based on the findings of the options analysis, summarizes the required components. The component interfaces and operational procedures will be identical with those discussed previously.

It is anticipated that the prototype implementation will require 18 months from initiation to operational checkout. Depending upon the date of initiation, some of the component recommendations may require modification to take advantage of the latest technological advances. These would include the availability of a solid-state microfiche scanner and improvement and cost-reduction of satellite links and earth stations. However, full implementation in the next several years can be based upon the overall MITS design described with appropriate improvements as new technologies are available.

Table 7.1. Prototype component recommendations.

Component Function	Recommended Hardware
Request Activation	CRT interactive terminal
Request Communication	110-band full-duplex, voice-grade link with standard modems
Request Buffering	Remote site controller memory
Master Fiche Duplication	Manual, rotating-platen, diazo duplicator
Pull List Printing	Standard computer output alphanumeric line printer
Fiche Scanning	Laser-beam spinning mirror scanner with automatic feed and X-Y positioner for image scan
Data Compression	Standard compressor hardware with tailored algorithm
Transmit Buffering	Solid-state memory
Data Transmission	Wide-band satellite link, 250 kbs one direction; portable earth station rental for demonstration
Receive Buffering	Solid-state memory
Data Expansion	Standard expander with recorder-tailored output
Recorder Buffering	Recorder controller memory
Microfacsimile Recording	Laser-beam spinning mirror recorder
Central Site Controller	Minicomputer processor/controller
Remote Site Controller	Recorder minicomputer processor/controller

8. TECHNOLOGY TRENDS AND THEIR IMPACT ON MITS

The technology areas which relate to MITS are many and varied. However, they all are rapidly changing. This is especially true in the areas of micrographics and electronics. Because these changes may greatly impact the cost of MITS, it is important that, during all phases of the project, project personnel are kept aware of these changing areas. The following paragraphs point out a few of the major trends and their expected impact on MITS.

HIGHLIGHTS OF PROMISING TECHNOLOGIES

CCD Scanners

As mentioned earlier in this report a very promising future technology that impacts MITS design is that of solid state or CCD scanners. At the time of this writing, there are a few operational bench versions of CCD scanners. However, none are developed to the stage equivalent to that of laser beam recorders. The primary advantage seen in CCD scanners is that the only moving part of the system will be the film transport mechanism, which is either a unitized fiche transport or roll film transport. As a consequence, reliability of the scanner will be very high. Moreover, CCD scanners will be significantly less expensive than any of the other scanners currently available. It is expected that within a year or two from this writing a solid state microfiche scanner will be available.

Optical Character Recognition (OCR)

One of the record preparation steps required for MITS is the attachment of machine-readable labels to each of the microfiche. This allows the scanning device to keep track of which fiche correspond to an individual record. This is necessary because the number of fiche in an individual record varies between individuals. At present, there are many optical character recognition projects and devices. However, none will universally read all character fonts, and all the devices are extremely expensive. Work is underway at places such as Rome Air Development Center to come up with new techniques and devices for reading handwritten material and all possible typewritten character fonts. If such a machine should eventually be available at a reasonable cost, it will be possible to eliminate the step of affixing machine-readable labels. One can simply incorporate into the scanning device an OCR device which reads the typewritten name and SSN on the fiche headers. Alternatively, the master fiche can be coded with a machine-readable code at the same time that the header label is placed on it. If this label is transparent so that it is picked up during the duplication process, the step of affixing the machine-readable labels can also be eliminated.

Holographic Microfiche

A project already referred to several times in this report is the human-readable, machine-readable task being conducted by Harris Electronics Corporation under the sponsorship of the Rome Air Development Center. Several significant spinoffs from this project

will be of benefit to MITS. It is possible that in the future the concept of holographic microfiche will also be of benefit. Potentially, the master record could be transformed into holographic records before the scanning process. This would allow for an extremely noise-insensitive transmission. It would also help to maintain the confidentiality of personnel records. The tradeoff that remains is to consider the impact of the additional step of production of holographic microfiche. It is conceivable, however, that the holographic microfiche could be created with the use of a computer, never actually producing a hard holographic record. Therefore, film costs would be saved.

Large-Scale Integration (LSI)

A continuing trend is for semiconductors and other electronic components to come down in cost. A prime example of this is the large scale integration (LSI) market. As more complex circuits become available and as their cost continues to decrease, MITS may require less and less initial expenditure.

Updatable Microfiche Copies

The development of a diazo or other contact copy film which is updatable will be of great importance to MITS. It will, in fact, be possible to refile the scanning copies of the microfiche with the silver master. When the master is updated the updatable copy can also be updated; therefore, the necessity for duplicating the master record each time it is requested is avoided. This will have a significant impact on the recurring cost of MITS. There is hope for such a film being developed as evidenced by the Scott Graphics updatable microfiche now being used in the Army personnel records system. A similar development for a copy fiche is not entirely unreasonable.

Automatic Storage and Retrieval

At present the Bureau of Naval Personnel does not maintain a separate file of diazo copies of the master records. However, if such a file were created as a working file MITS could take maximum advantage of its existence. It is conceivable that the file could be housed in an automatic storage and retrieval device. The device could be driven by the output of the system controller directly rather than by manually entering a retrieval command. The fiche extracted from the automatic storage and retrieval device could be transported directly to the scanner. This would eliminate several operational steps at the central site and, thus, take maximum advantage of automation and the corresponding labor savings.

Lower Cost Earth Station

The most significant cost of MITS is the link cost. The link costs are made up of the space or satellite component and any necessary land line or terrestrial components. The terrestrial costs are necessary if there are no earth stations located at the central and remote site and users cannot be found to share the earth station rental and installation costs. However, as the cost of electronics components decreases, it is conceivable that the cost of an earth station might decrease so much that earth stations could be bought and located directly at both the remote and central sites with no requirement for user sharing. If this happened the terrestrial link option and associated costs mentioned earlier would be eliminated altogether, resulting in a significant savings in overall cost.

Digital Microfiche

A recent technological development is the high-density storage of information on microfiche. Digital Recording Corporation has patented a technique invented at the Battelle Memorial Institute, Northwest Laboratory, which allows an entire 30-minute television program to be recorded on a microfiche the size of an IBM card. It is possible that substantial numbers of the BUPERS records could be transferred to this media in a digitized form. Placed in an automatic storage and retrieval device capable of randomly accessing any one of the records, they would be available for immediate response to retrieval requests. However, this technology is perhaps 5 or 10 years away from low-cost availability development, and, therefore, is not immediately applicable to MITS needs.

SUMMARY

All of the above sections address technological trends which impact the cost and effectiveness of MITS. In general, they reflect the trends of labor costs increasing and the associated electronics costs decreasing. It is therefore important that the MITS task team keep a close watch on the appropriate technologies for near-future developments which will directly affect the implementation of MITS. It is expected that many of these developments will be favorable and greatly enhance the cost-effectiveness of MITS.

9. SUMMARY AND RECOMMENDATIONS

SUMMARY

As a result of the Options Analysis, the preliminary design, and the cost estimate studies of MITS (Reference 9.1), the following conclusions were reached:

1. There are still three options available to BUPERS for transmitting microfiche records over long distances. They are

   a. Microfacsimile (MITS)

   b. Air Freight

   c. U. S. Mail

      (1) Batch delivery

      (2) Individual delivery

2. MITS, the most technologically advanced of these options, is now within the state-of-the-art, requiring no R&D to develop a functional system. Only system design, application engineering, and system integration are required. The other two options are conventional, and could be implemented with no new development.

3. MITS provides the most reliable and most rapid long-distance transmission of microfiche available. Actual transmission time will average 4 minutes per record and total turnaround from request of record to receipt of record can be less than 1 hour. To handle the projected volume of 300 records per day in an orderly fashion, the standard turnaround time will be 48 hours.

4. MITS has the highest initial costs and the highest recurring costs. These costs are compared to the alternative system costs in Table 9.1

Table 9.1. Relative costs.

Microfiche Transmission Technique	One-Time Costs	Recurring Yearly Costs
MITS (1976)	12.5	3.6
Air Freight	1.1	1.0
U. S. Mail (certified batch)	1.1	1.0
Individual service certified mail	0.1	1.1

5. As a result of the higher one-time and recurring costs for MITS, the requirement to transmit large volumes of microfiche is not a sufficient justification for implementing a sophisticated microfacsimile system.

6. The major factors which justify a microfacsimile system are these:

a. A requirement for rapid access such as for health, emergency, or disaster. These include applications for strategic information delivery to ships at sea and emergency delivery of medical history for at-sea use.

b. A requirement for increased reliability and security of document transmission.

7. Diazo copies of silver master microfiche can be reliably scanned with laser beam scanners. The wavelength of the scanning laser has minimal impact on the scanned image signal quality.

8. A more desirable scanner will be available in the next 1 to 2 years that is based on a charge-coupled-device line-array that will be less expensive and more reliable than the spinning mirror laser scanner.

9. It is practical to reliably stack and automatically feed diazo duplicate microfiche into a scanner, and a system was found which currently performs this function as well as X-Y positions the fiche in front of the scanning beam.

10. An image-packed format for the output microfiche has been developed and successfully tested with Naval personnel. This format was judged equally acceptable with the standard format; and, offers the advantage of a 75-percent reduction in output film costs.

11. A legibility criteria and calibration procedure has been developed which employs a microfiche of IEEE facsimile chart images to ensure adequate legibility.

12. A satellite transmission link is the most economical for long-distance image data transmission. Significant cost savings can be realized if the earth station facilities are shared with a number of other users, since the facility cost is much larger than the actual bandwidth costs. Installation of an earth station in the vicinity of each remote site also eliminates very high land line costs for remote coupling between existing earth stations and the selected remote sites.

13. Labor costs and therefore postal costs are increasing at a rapid rate. At the same time, electronic component and data transmission costs are reducing. Therefore MITS will become more cost-effective with time. In the next 10 to 20 years, it is anticipated that the recurring costs of MITS will be lower than those of the optional systems.

14. A low-volume, low-cost microfacsimile system can be built with existing technology for rapid, reliable, priority transmission of BUPERS microfiche.

RECOMMENDATIONS

Based upon the findings of the MITS Options Analysis and preliminary design study, recommendations are now presented for (1) the detailed design for implementation of MITS, and (2) the course of action for BUPERS for providing the microfiche access service.

The recommended design features for MITS are the following:

1. The scanning resolution is 151 pixels per millimeter (3,840 pixels per inch) and 151 scan lines per millimeter (3,840 lines per inch).

2. The scanner is a laser-beam spinning mirror scanner. This scanner will proceed image-by-image and skip the blank image areas on the input fiche. Fiche input is recommended over a roll film input.

3. The recommended laser for scanning is a helium-neon laser.

4. The recommended output recorder is a laser-beam spinning mirror recorder. The recorder will actually be identical to the scanner so that each unit could be used for either input or output.

5. The recommended output film with adequate resolution and sensitivity to match the laser recorder is a dry-processed, silver-halide film. Dry-processed silver film is less expensive than wet silver because there is no cost for processing chemicals.

6. The film processor should be an integral part of the recorder such that the output of the recorder will be processed, cut, and dried microfiche.

7. The recommended transmission link is a wide-band satellite link with an earth station located near the remote sites. This earth station should be shared with as many non-MITS users as is practical with the rental cost shares based proportionally on bandwidth used.

8. The image-packed format is recommended for the MITS output microfiche.

The recommended action for BUPERS to take on providing the remote access service to Navy users is the following:

1. Normal BUPERS microfiche transmission requirements should be fulfilled by mailing the records to individuals.

2. The normal mailing system should be augmented by a low-volume microfacsimile system which ties in to major Navy centers for priority service.

3. A prototype low-volume, two-way transmission microfacsimile system should be implemented between Washington, D.C., and San Diego to demonstrate this priority service.

4. BUPERS should investigate the feasibility of producing small, low-volume, low-cost microfacsimile receivers for small-station and shipboard access to the microfiche records.

5. BUPERS should monitor the technology trends and postal cost trends to maintain updated awareness of the cost-effectiveness of MITS versus the alternative systems described in this report.

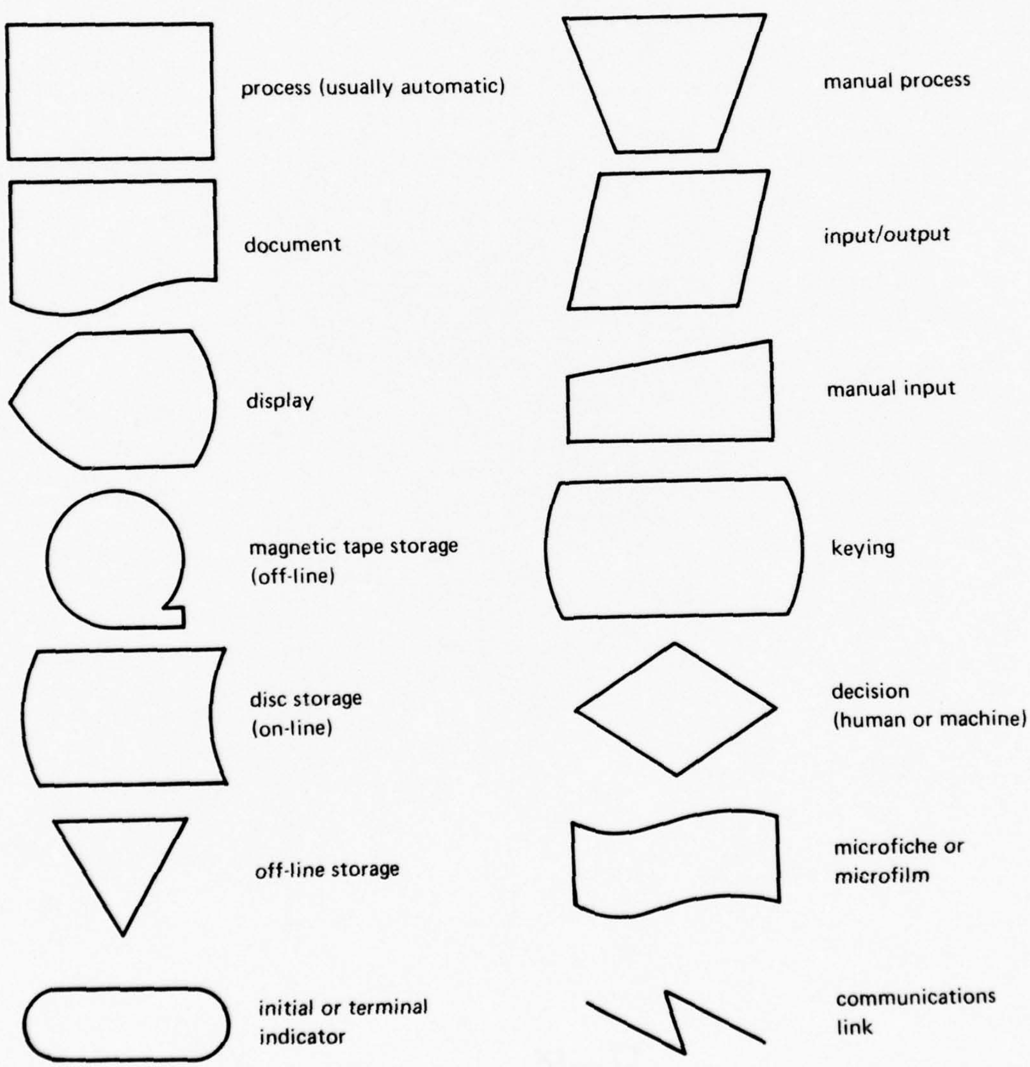
REFERENCE

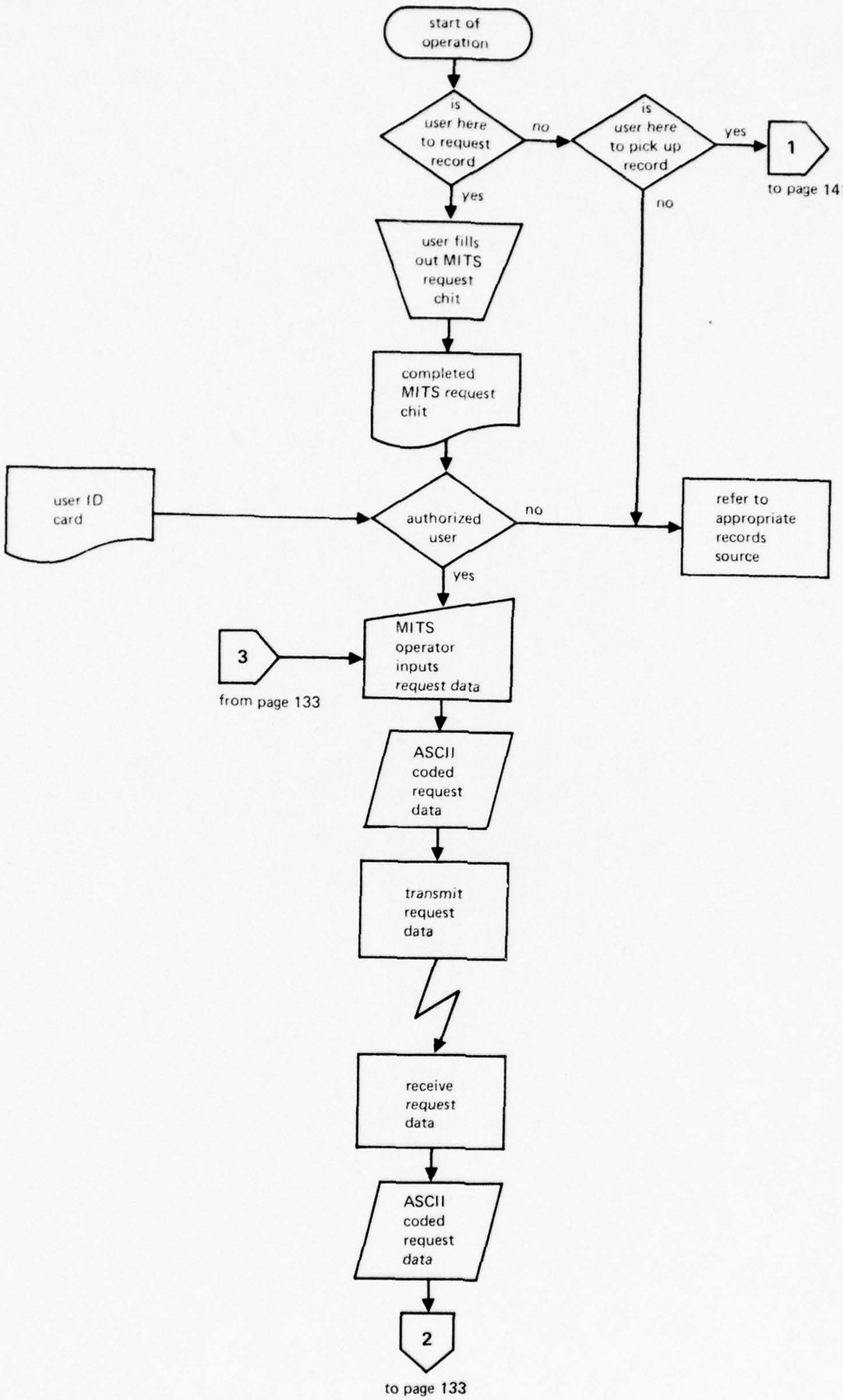
9.1 Naval Undersea Center. NUC Technical Note 1752, Cost Estimates and Alternative Systems for the Bureau of Naval Personnel's Microfiche Image Transmission System (MITS), by D. Solarek and D. Endicott. December 1976.

APPENDIX A:
MITS FLOW DIAGRAM

The following pages contain a logical flow diagram for the entire MITS. All human and machine functions are presented. The table below defines the symbols used in the flowchart. For the most part, the flow conventions and symbols are standard to computer programming and hardware systems.

Table A.1. MITS flow diagram symbols.





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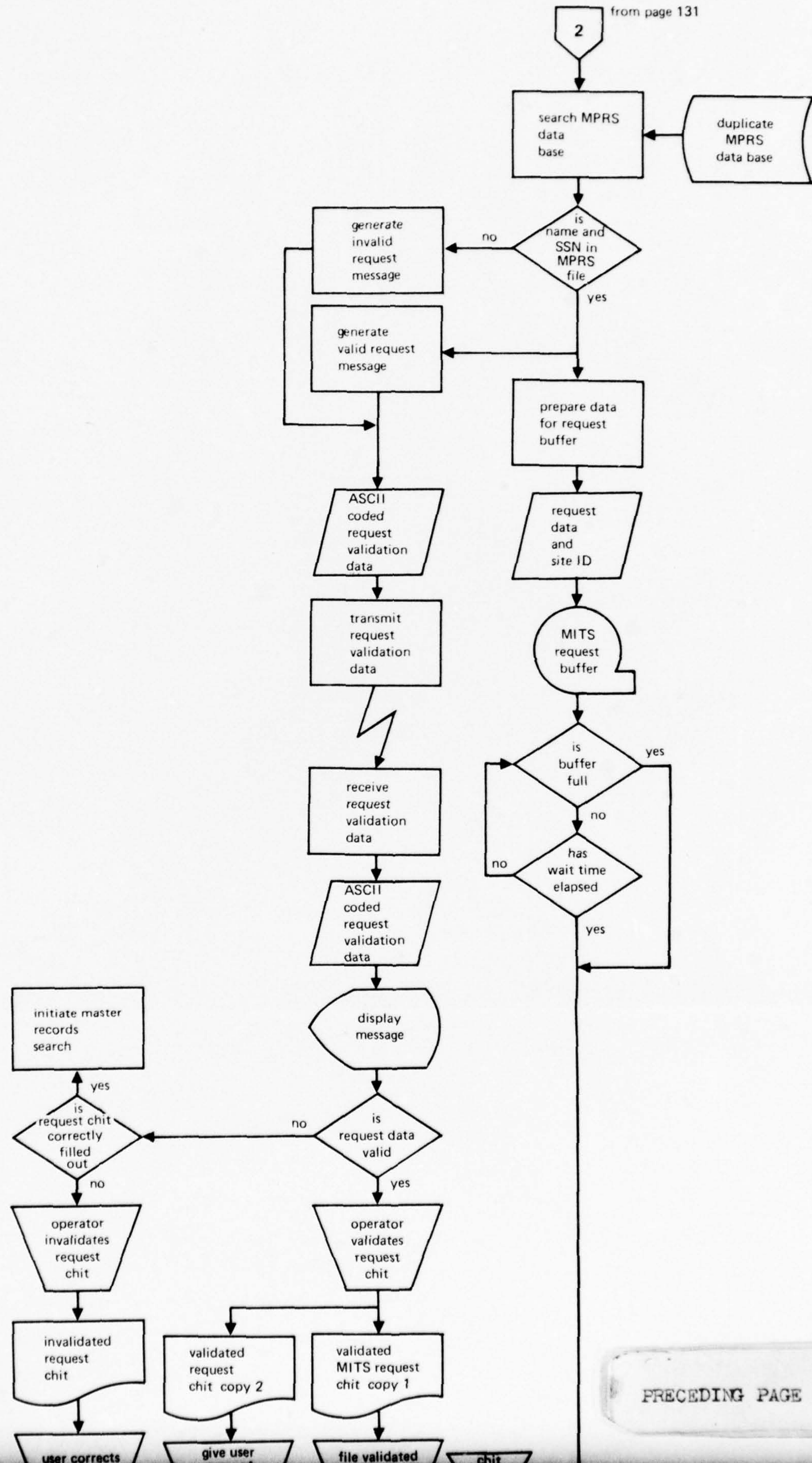
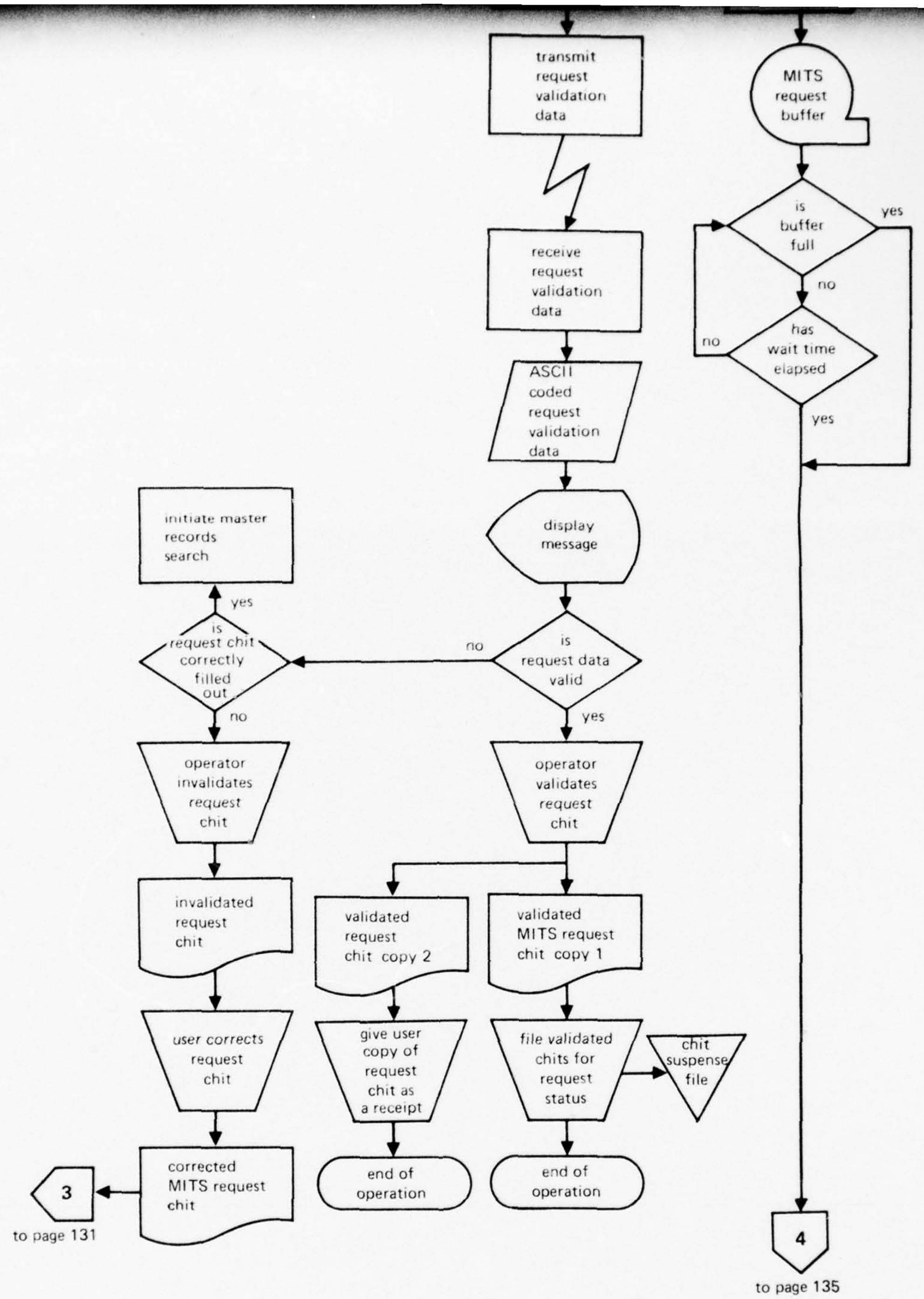
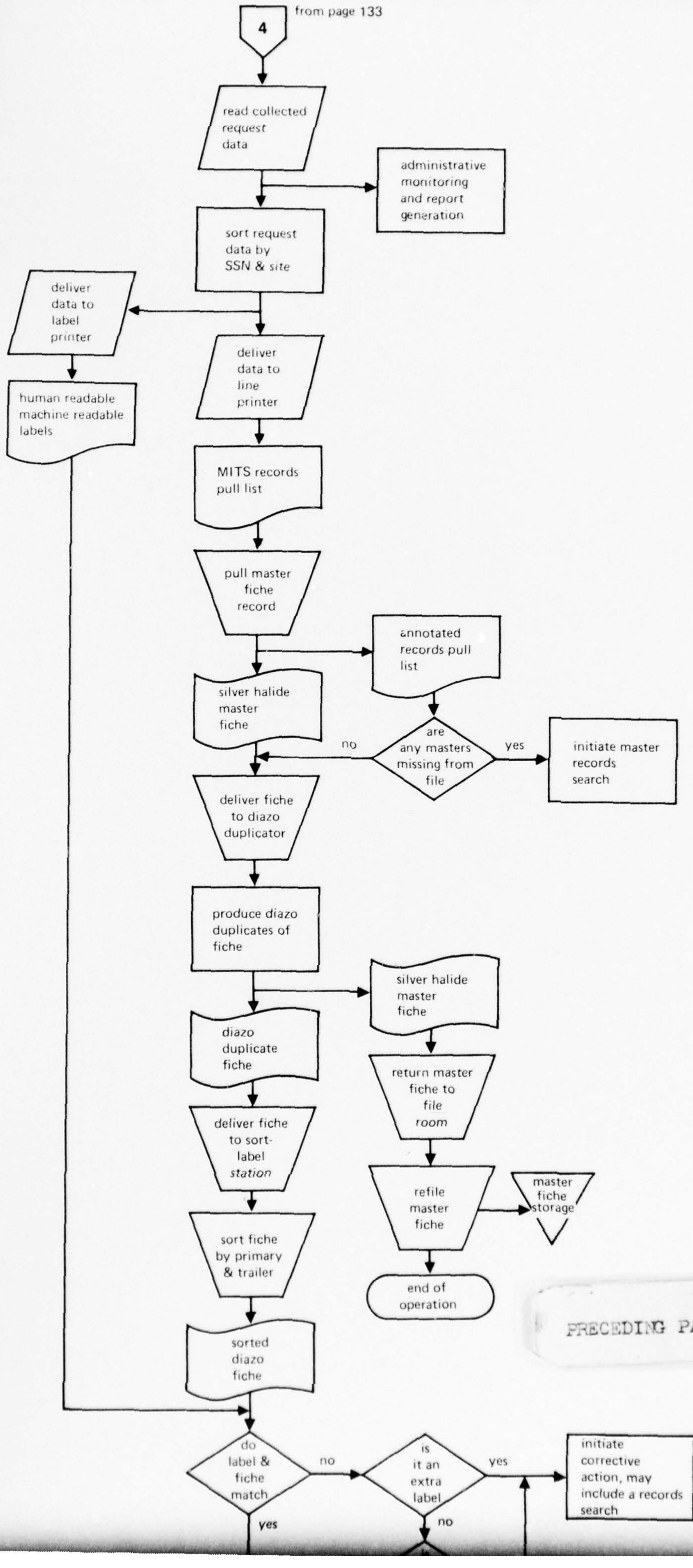

2
from page 131
search MPRS data base
duplicate MPRS data base
is name and SSN in MPRS file
no
yes
generate invalid request message
generate valid request message
prepare data for request buffer
ASCII coded request validation data
request data and site ID
transmit request validation data
MITS request buffer
is buffer full
yes
no
has wait time elapsed
no
yes
receive request validation data
ASCII coded request validation data
display message
initiate master records search
yes
is request chit correctly filled out
no
is request data valid
no
yes
operator invalidates request chit
operator validates request chit
invalidated request chit
validated request chit copy 2
validated MITS request chit copy 1
user corrects
give user
file validated
chit


transmit request validation data
MITS request buffer
is buffer full
yes
no
has wait time elapsed
no
yes
receive request validation data
ASCII coded request validation data
display message
initiate master records search
yes
is request chit correctly filled out
no
is request data valid
no
yes
operator invalidates request chit
operator validates request chit
invalidated request chit
validated request chit copy 2
validated MITS request chit copy 1
user corrects request chit
give user copy of request chit as a receipt
file validated chits for request status
chit suspense file
corrected MITS request chit
end of operation
end of operation
3
to page 131
4
to page 135



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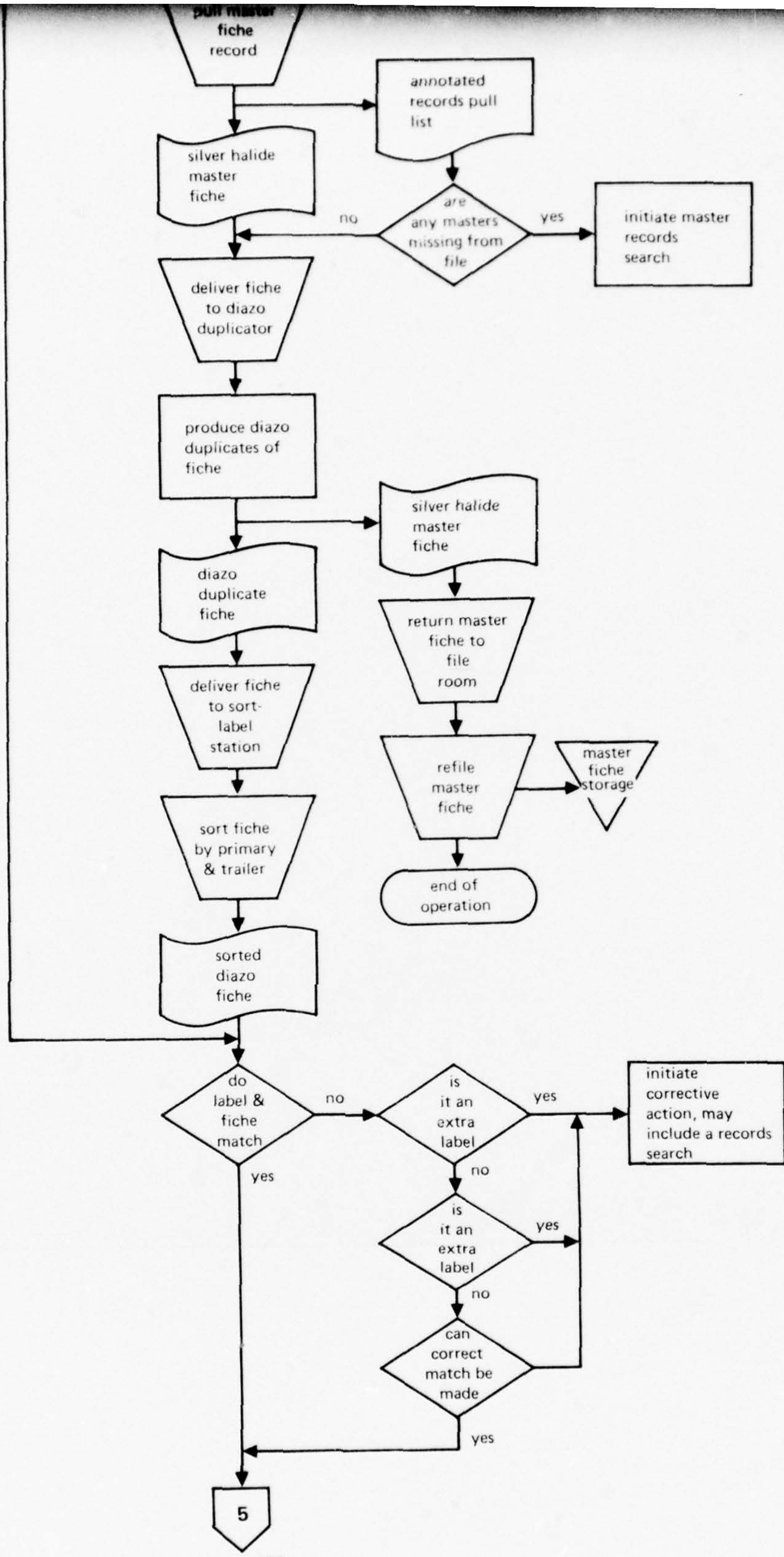
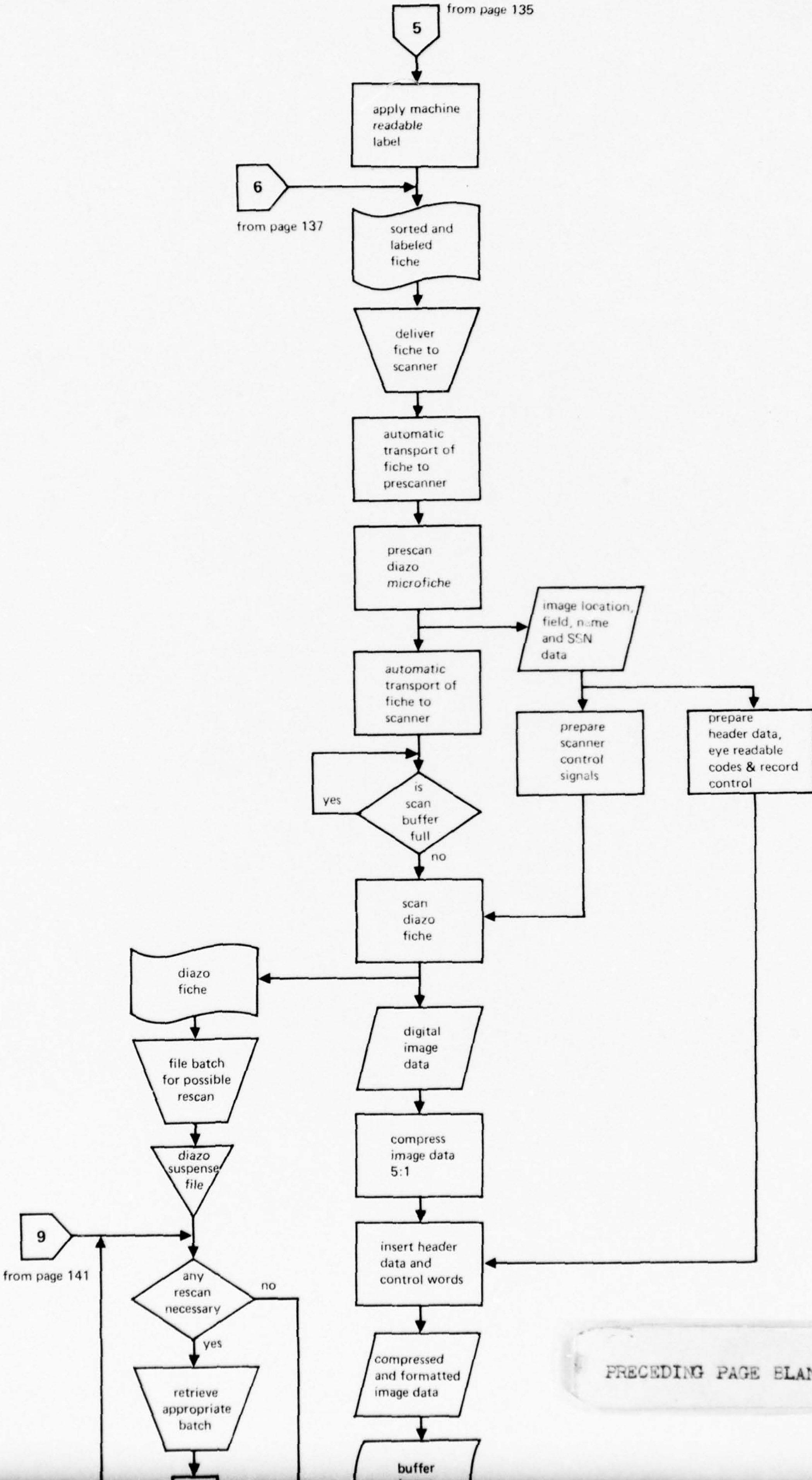

pull master fiche record
annotated records pull list
silver halide master fiche
are any masters missing from file
no
yes
initiate master records search
deliver fiche to diazo duplicator
produce diazo duplicates of fiche
silver halide master fiche
diazo duplicate fiche
return master fiche to file room
deliver fiche to sort-label station
refile master fiche
master fiche storage
sort fiche by primary & trailer
end of operation
sorted diazo fiche
do label & fiche match
no
yes
is it an extra label
yes
no
initiate corrective action, may include a records search
is it an extra label
yes
no
can correct match be made
yes
5

to page 137



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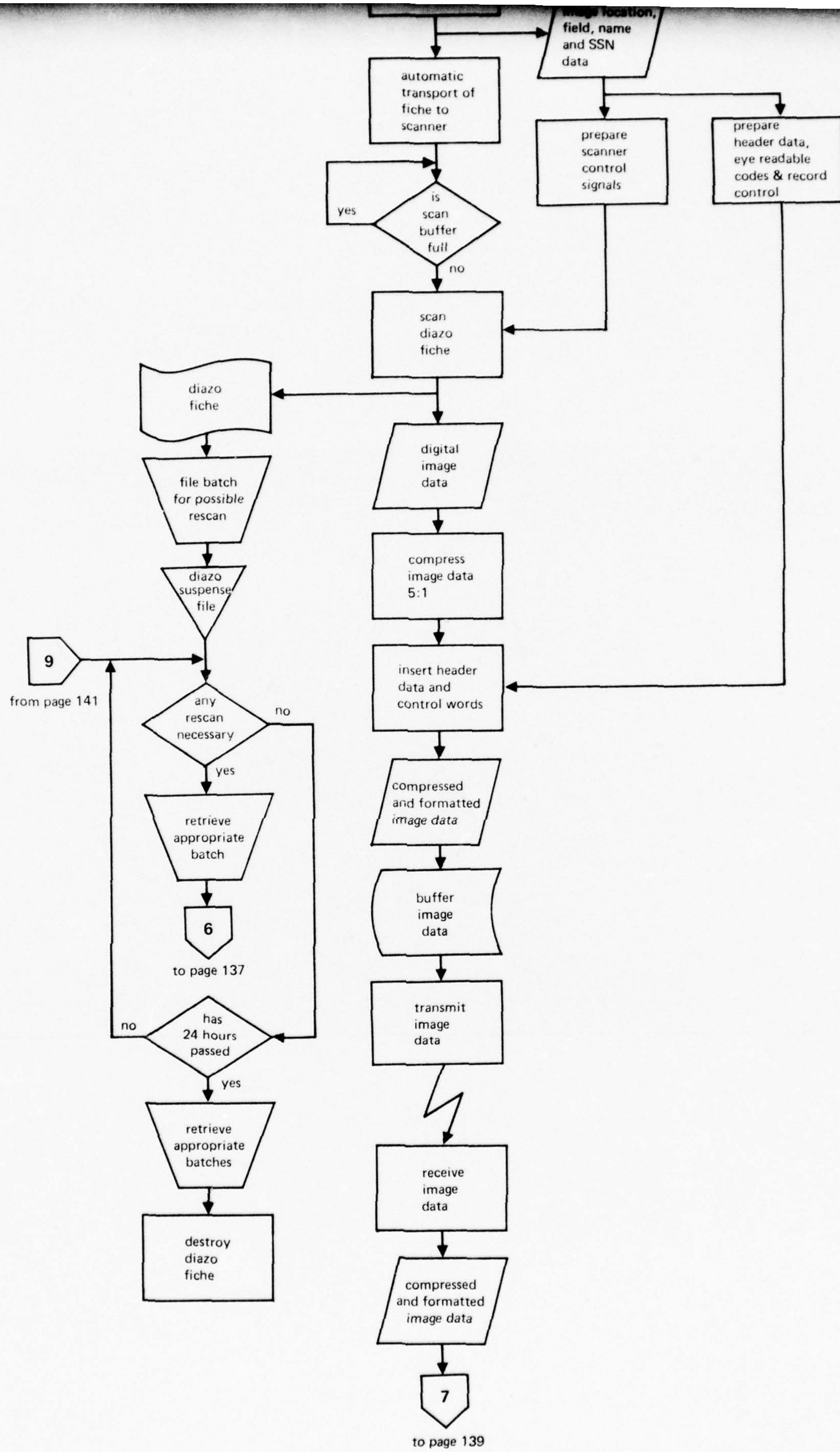
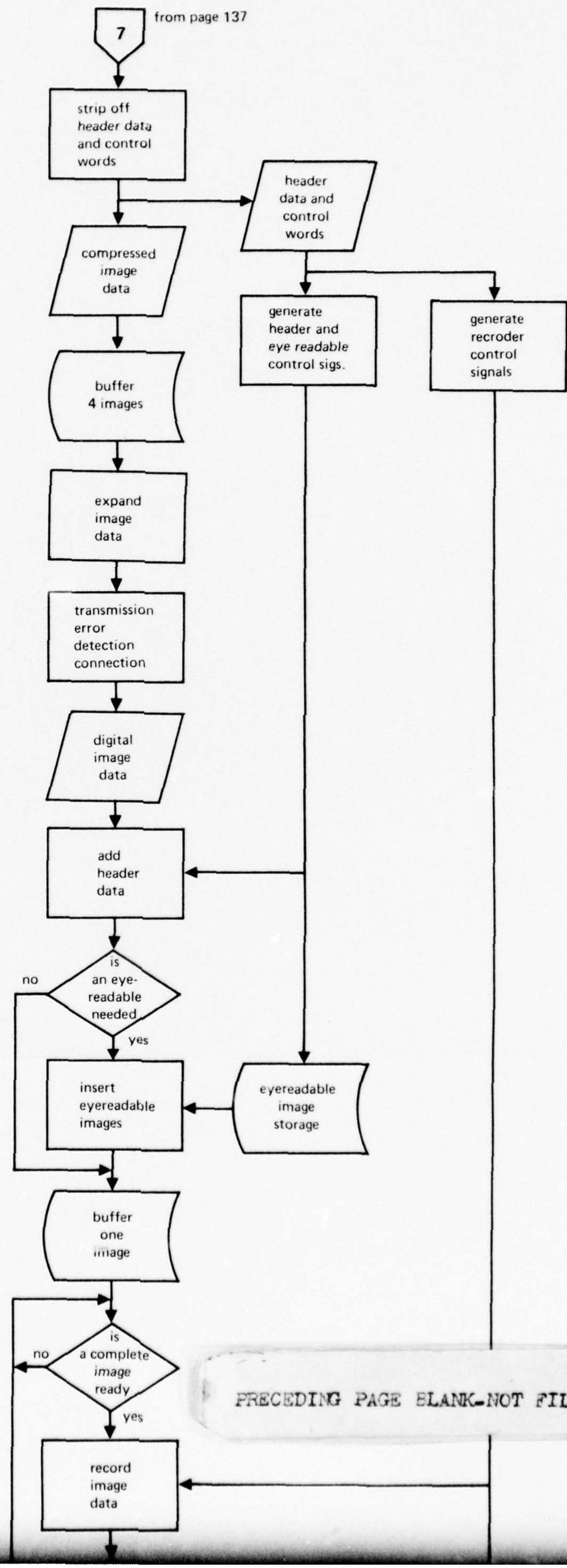


image location, field, name and SSN data
automatic transport of fiche to scanner
prepare scanner control signals
prepare header data, eye readable codes & record control
is scan buffer full
yes
no
scan diazo fiche
diazo fiche
digital image data
file batch for possible rescan
compress image data 5:1
diazo suspense file
9
from page 141
insert header data and control words
any rescan necessary
no
yes
compressed and formatted image data
retrieve appropriate batch
buffer image data
6
to page 137
transmit image data
has 24 hours passed
no
yes
retrieve appropriate batches
receive image data
destroy diazo fiche
compressed and formatted image data
7
to page 139



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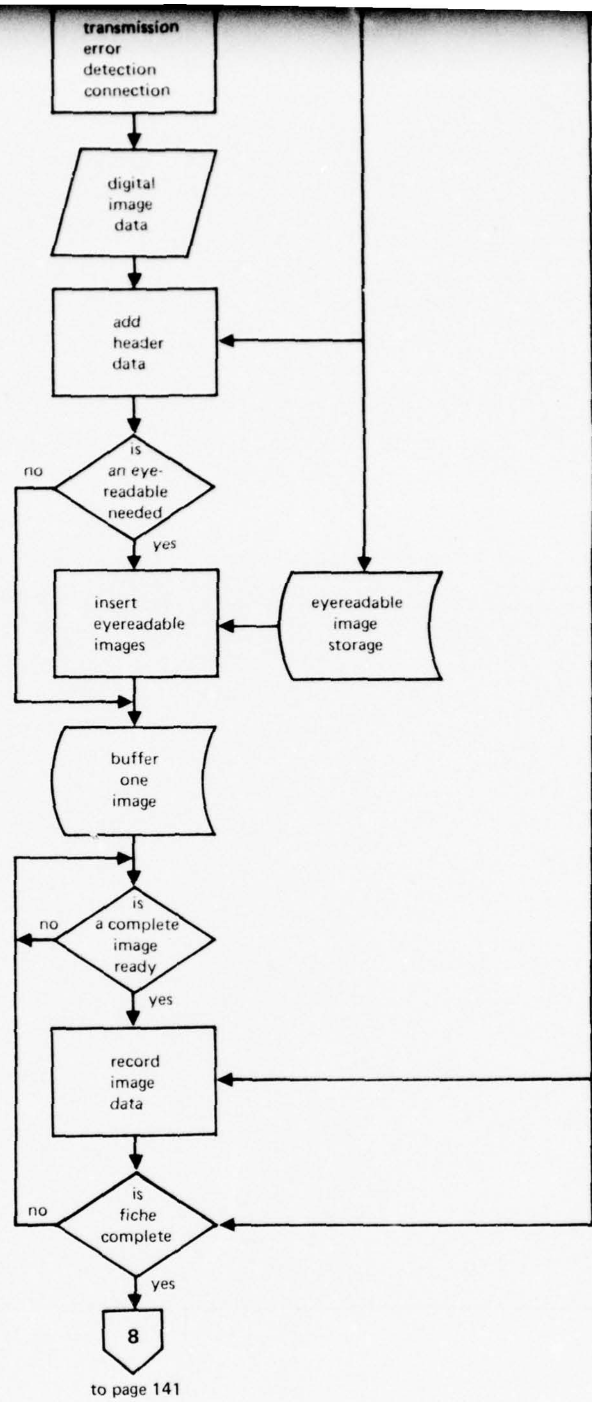
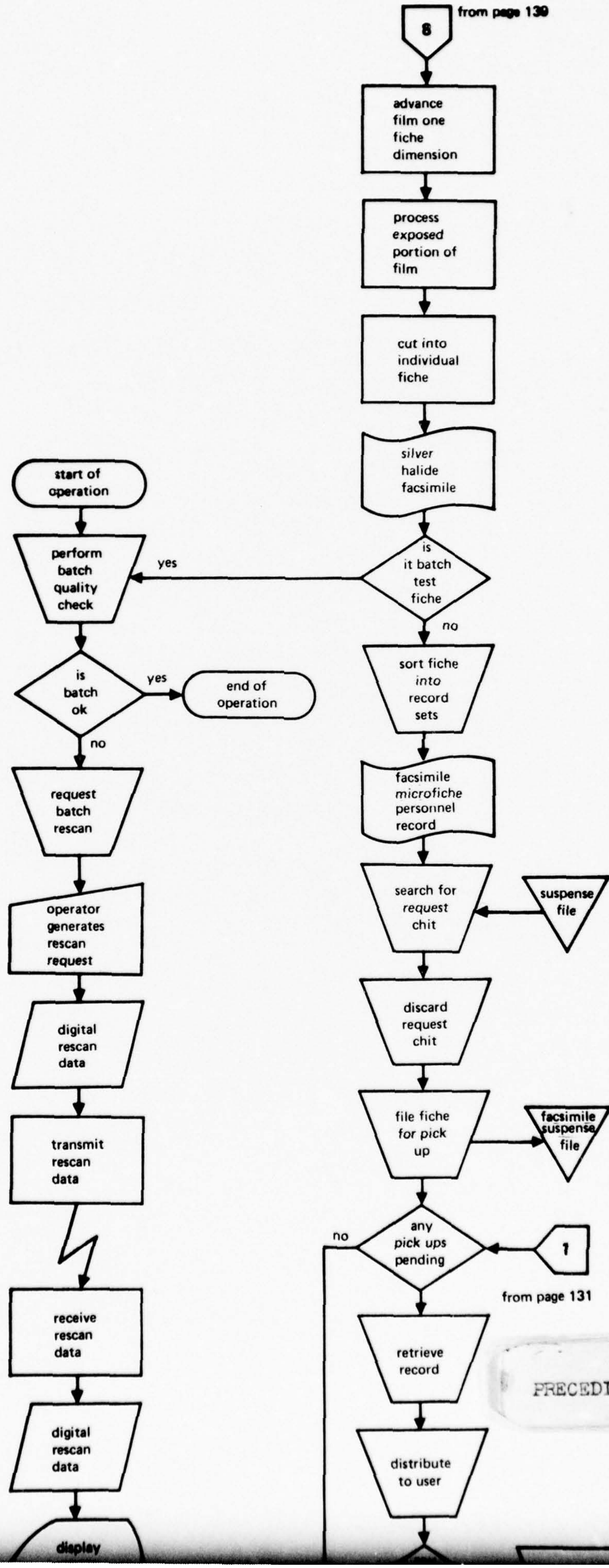
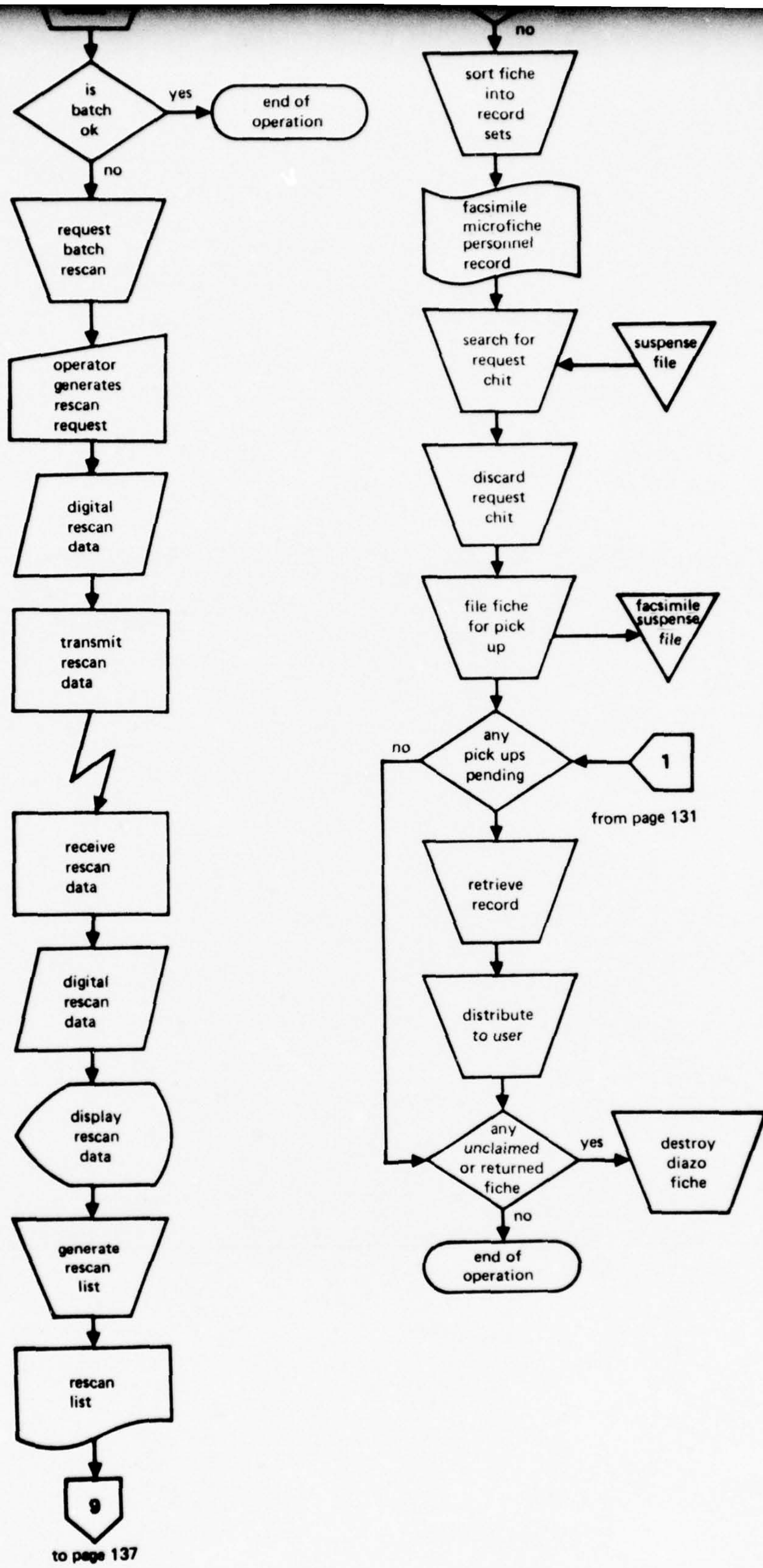

transmission
error
detection
connection
digital
image
data
add
header
data
is
an eye-
readable
needed
no
yes
insert
eyereadable
images
eyereadable
image
storage
buffer
one
image
is
a complete
image
ready
no
yes
record
image
data
is
fiche
complete
no
yes
8
to page 141



8
from page 139
advance film one fiche dimension
process exposed portion of film
cut into individual fiche
silver halide facsimile
is it batch test fiche
yes
no
start of operation
perform batch quality check
is batch ok
yes
end of operation
no
request batch rescan
operator generates rescan request
digital rescan data
transmit rescan data
receive rescan data
digital rescan data
display
sort fiche into record sets
facsimile microfiche personnel record
search for request chit
suspense file
discard request chit
file fiche for pick up
facsimile suspense file
any pick ups pending
no
1
from page 131
retrieve record
distribute to user


is batch ok
yes
end of operation
no
request batch rescan
operator generates rescan request
digital rescan data
transmit rescan data
receive rescan data
digital rescan data
display rescan data
generate rescan list
rescan list
9
to page 137
no
sort fiche into record sets
facsimile microfiche personnel record
search for request chit
suspense file
discard request chit
file fiche for pick up
facsimile suspense file
any pick ups pending
no
1
from page 131
retrieve record
distribute to user
any unclaimed or returned fiche
yes
destroy diazo fiche
no
end of operation

APPENDIX B:
MITS SUMMARY POSITION DESCRIPTION

REMOTE SITE

Principal Receptionist (first shift only) GS-9

This position requires a skilled office manager with supervisory abilities. The incumbent is responsible for the entire operation of the MITS remote site. The incumbent supervises other MITS remote site personnel, provides training as required, evaluates performance, grants leave and performs other managerial functions. The incumbent coordinates the work of remote site personnel and greets records requesters, verifies requester identities, key strokes request data, verifies correctness of requests and validates request forms. The incumbent retrieves facsimile records and distributes them to authorized requesters. General office duties such as answering telephone, filing, typing record keeping and reporting are also part of this position. Incumbent may also perform intersite communications for administrative or records tracking purposes. Incumbent's supervisor is the Head, Microform Operations Branch (Military).

Production Controller (first shift)* GS-5

This position requires a production technician with electro-mechanical abilities. The incumbent monitors the status of all remote site equipment and coordinates failure correction with service contractor and keeps appropriate reliability records. The incumbent loads the film processor with chemicals and film, performs appropriate system checks, tuning, alignment, testing and adjustments. The remote site quality control checks and intersite communication duties are performed by the incumbent. In addition, as required by workload, the incumbent will greet records requesters, verify requester identity, keystroke request data, verify correctness of requests and validate request forms. The incumbent retriever facsimile records and distributes them to authorized requesters.

CENTRAL SITE

Service Control Supervisor (first shift only) GS-7

The position requires a skilled office manager with supervisory abilities. The incumbent monitors the central site controller for production of pull lists and machine readable labels. The incumbent delivers the pull lists to the MPRS master retrieval station, loads the

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**Second shift production controller will complete any of day's leftover fiche records inspection, sorting, filing, or disposal. Attends to other duties listed above (except request intake function) and is responsible for major portion of minor maintenance, cleaning, and replenishment. Is in charge of facility during this non-office shift.*

**Third shift production controller carries out remaining duties for operational day but is especially responsible for overseeing major down-time or unusual maintenance which will be performed during the first four hours of the third shift (coordinates). Is in charge of facility during this non-office shift.*

machine readable labels into the attaching machine, and is responsible for administrative interfacing with the MPRS. Incumbent performs intersite communications for administrative or records tracking purposes. In addition incumbent is responsible for the entire operation of the MITS central site. The incumbent supervises other MITS central site personnel, provides training as required, evaluates performance, grants leave and performs other managerial functions. General office duties such as telephoning, filing, typing, record keeping and reporting are also part of this position. Incumbent's supervisor is the Head, Office Records Branch (Military).

Production Controller (first shift)* GS-5

This position requires a production technician with electro-mechanical abilities. The incumbent monitors the status of all remote site equipment and coordinates failure correction with service contractor and keeps appropriate reliability records. Incumbent rearranges diazo record copies to accommodate image packing during scanning, carries out procedures for automatic attachment of machine readable labels, places tray of prepared fiche into scanner and completes transmission to remote site. Incumbent is responsible for operating condition of MITS central equipment, loads computer and teletype printers with paper, performs appropriate system checks, tuning, alignment, testing, adjustments, and minor maintenance as required to maintain a smooth operation. Incumbent is crosstrained in between site teletype communications for administrative and records tracking purposes.

**Second shift production controller will complete any of day's leftover fiche retrieval, sorting and labeling, scanning, filing, or disposal tasks. Attends to other duties listed above and is responsible for major portion of minor maintenance, cleaning and replenishment. Is in charge of facility during this non-office shift.*

**Third shift production controller carries out remaining duties for operational day but is especially responsible for overseeing major down-time or unusual maintenance which will be performed during the first four hours of the third shift. Is in charge of the facility during this non-office shift.*

APPENDIX C:
DEFINITIONS OF SELECTED TERMS AS USED IN THIS REPORT

1. Active Scan Ratio. The percentage of the time during a scanner cycle when valid data is produced.

2. Aperture Cards. An aperture card is a tabulating card with a rectangular hole specifically prepared for the mounting of a frame of microfilm.

3. Asynchronous. Occurring at random times not related to any clock.

4. Audit Log. A record of transactions stored in a computer file or manual record used to monitor performance.

5. Automatic Handling. Any automatic transport of microfiche to or from a scanner or recorder. Transport can include loading from a stack, presentation to a camera or lens, coordinate locating of particular frames on a microfiche, or unloading and restacking.

6. Background Density. The background density is the visual diffuse transmission density of the nonline and noncharacter portion of the document image area.

7. Baud. A rate unit for data transmission corresponding to one basic element per unit time.

8. Blowback. Reenlargement of microimages to eye-readable document size.

9. Clock. A timing signal used for sequencing operations.

10. Column. A vertical series of microimages.

11. Contrast. The measure of difference in gray levels of an image. A typical high-contrast image is a black (or white) character on a white (or black) background.

12. Definition. Distinctness or clarity of detail or outline in an output record or other reproduction.

13. Density (in facsimile). A measure of the light transmitting or reflecting properties of an area. It is expressed by the common logarithm of the ratio of incident to transmitted or reflected light flux.

14. Diazo Copy. A duplicate of a master fiche made on diazo film.

15. Diazo Film. An ultraviolet light sensitive, vegetable dye based film that is developed in an ammonia bath.

16. Document. Document applies to the specifications, drawings, sketches, lists, standards, pamphlets, reports, and printed, typewritten, or other information which can be single or multiple page.

17. Document Image Area. The document image area is the total area which contains the image of one or more sheets or pages of a document or portions of a document.

18. Dump. The transfer of data out of a storage device.

19. Electronic Raster Scanning. That method of scanning in which motion of the scanning spot in both dimensions is accomplished by electronic means.

20. Eye-Readable. Legible without magnification.

21. Facsimile. A copy of an original document. For this report, facsimile will indicate an eye-readable document that has been scanned or machine read at one site and reconstructed in eye-readable size without actual transport of the original document.

22. Facsimile (in electrical communications). The process, or the result of the process, by which fixed graphic material including pictures or images is scanned and the information converted into signals which are used either locally or remotely to produce in record form a likeness (facsimile) of the subject copy.

23. Facsimile Resolution. The sensing or writing rate for full-size documents as expressed in elements or lines per inch of full-size copy. The facsimile resolution of 24X reduction microfiche equals 1/24 of the scanning resolution.

24. Facsimile Transmission. The transmission of signal waves produced by the scanning of fixed graphic material, including pictures, for reproduction in record form.

25. Fiche. Same as microfiche.

26. Files. Blocks of storage that can be identified for loading and dumping.

27. Frame, Microfiche. A microfiche frame is a geometric subdivision of the grid. A microimage and margin are contained within a frame.

28. Frame, Microfilm. The frame is the total area of microfilm used in one exposure regardless of whether or not the area is filmed by the document image area.

29. Generation. A measure of the remoteness of a particular copy from the original material. That is, a diazo duplicate of a master fiche is a second-generation copy.

30. Grid Area Size. An area 11.20 millimeters by 15.95 millimeters on the microfiche which corresponds to the microfiche frame.

31. Hard Copy. An enlarged copy of a microimage, usually on paper.

32. Hard Failure. A failure that cannot be corrected without termination of operation for replacement or adjustment.

33. Image. As used in this report, image refers to the area occupied by an 8 1/2- by 11-inch document, either full-size or photoreduced.

34. Infant Mortality. The period of high failure rate following initial operation of new devices.

35. Interactive. Activities in which the participants respond to one another's actions.

36. Interrupt Control. Computer input mode that allows external devices to request operation by the computer.

37. Latency. The length of delay between request of an action and its initiation.

38. Legible. Capable of being read or distinguished. In reference to recorder output microfiche, legible indicates that all the characters in context of a document are readable by the average person.

39. Load. The transfer of data into a storage device.

40. Machine readable. Detected by an automatic device without manual action.

41. Margin (image). The nonimage area between the microimage and the grid line is the margin.

42. Master Fiche. Microfiche of silver halide images mechanically attached to a transparent substrate.

43. Microfacsimile. Same as facsimile but restricted to reconstruction of a microform document from either a microform or a full-size original document.

44. Microfiche. Microfiche is a sheet of film which contains microimages. It usually contains a title which can be read by the unaided eye.

45. Microform. A generic term for any form (either film or paper), strip, roll, or sheet which contains microimages.

46. Microimage. A 24X photoreduced image.

47. Modem. Modulator/Demodulator to allow digital devices to communicate over analog paths.

48. Multiple Spot Scanning. The method in which scanning is carried on simultaneously by two or more scanning spots, each one analyzing its fraction of the total scanned area of the subject copy.

49. Noise. Any extraneous electrical disturbance tending to interfere with the normal reception of a transmitted signal.

50. Nominal Line Width. The average separation between centers of adjacent scanning or recording lines.

51. Optical Resolution. The ability of optical systems and photomaterials to render visible fine detail of an object. It is usually expressed in lines per millimeter (or inch, as appropriate).

52. Overhead Information. Nonimage data, necessary for the control of the process, that moves with the image data.

53. Page. The area occupied by an 8 1/2- by 11-inch document, either full-size or photoreduced (same as image).

54. Photographic Resolution. Refers to the ability to distinguish two closely spaced objects, usually black and white bars or lines as being separate. Photographic resolution is measured in line pairs per millimeter, (same as photographic lines per millimeter) and corresponds to the highest linear density of distinguishable black and white bars.

55. Photosensitive Recording. Recording by the exposure of a photosensitive surface to a signal-controlled light beam or spot.

56. Priority Interface Module. Computer input device which selects signals for action according to a predetermined priority ordering.

57. Random Access Memory. Storage locations for data that may be individually selected in any order desired.

58. Raster. A predetermined pattern of scanning lines that provides substantially uniform coverage of an area. In television and the scanning systems discussed in this report, the raster is seen as closely placed parallel lines and is most evident when there is no image.

59. Real-Time Events. Their validity is dependent upon their occurrence at a specific point in time.

60. Receiver, Facsimile. The apparatus employed to translate the signal from a communications channel into a facsimile record of the subject copy.

61. Record Medium. The physical medium on which the facsimile recorder forms an image of the subject copy.

62. Record, Microfiche. Refers to a set of microfiche which contains a complete file of personnel records for an individual officer or enlisted person.

63. Recorder, Facsimile. That part of the facsimile receiver which performs the final conversion of an electrical picture signal to an image of the subject copy of the record medium.

64. Recording (in facsimile). The process of converting the electrical signal to an image on the record medium.

65. Reduction Ratio. The term reduction ratio as used throughout this report means the ratio of the linear measurements of a document image area to the linear measurement of the microimage of that same document image area.

66. Resolving Power. Same as photographic resolution.

67. Row. A horizontal series of microimages.

68. Scanner. (a) A device which passes a focused beam of energy through a microfilm document image to a sensor where the optical information is transformed into digital electronic data. (b) That part of the facsimile transmitter which systematically translates the densities of the subject copy into signals.

69. Scanning (in facsimile). The process of analyzing successively the densities of the subject copy according to the elements of a predetermined pattern.
NOTE: The normal scanning direction is from left to right and top to bottom of the subject copy as when reading a page of print. Reverse direction is from right to left and top to bottom of the subject copy.

70. Scanning Resolution. The sensing or writing rate across the aperture of a scanning device. This corresponds to the actual sample rate for a scanner or recorder as expressed in lines per inch.

71. Scanning Spot (in facsimile). The area on the subject copy viewed instantaneously by the pickup system of the scanner.

72. Signal Contrast (in facsimile). The ratio expressed in decibels between white signal and black signal.

73. Simple Scanning. Scanning of only one scanning spot at a time during the scanning process.

74. Skew (in facsimile). The deviation of the received frame from rectangularity due to asynchronism between scanner and recorder. Skew is expressed numerically as the tangent of the angle of this deviation.

75. Subject Copy. The material in graphic form which is to be transmitted for facsimile reproduction.

76. Tabulating Card. A tabulating card is a card on which data is entered by use of punched holes or other means that can be sensed by machine, so that it can sort, collate, list, total, or otherwise manipulate the card or the data. A tabulating card may at times be referred to as a tab card.

77. Through Data Rate. The average quantity per unit time of data a device inputs, processes, and outputs.

78. Transmitter, Facsimile. The apparatus employed to translate the subject copy into signals suitable for delivery to the communication system.

79. Vesicular Film. Film that has a light-sensitive element suspended in a plastic layer and that, upon exposure, creates strains within the layer. The latent image is made visual by heating the plastic layer, resulting in the formation of minute bubbles or vesicles.

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